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THE TREATMENT OF DAIRY PLANT WASTES

Kraftco Corporation

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THE TREATMENT OF DAIRY PLANT WASTES

UPGRADING DAIRY PRODUCTION AND TREATMENT FACILITIES TO CONTROL POLLUTION

MADISON, WISCONSIN

MARCH 20 - 21, 1973

PREPARED FOR THE ENVIRONMENTAL PROTECTION AGENCY

TECHNOLOGY TRANSFER PROGRAM

COMPILED BY:

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CURRENT PRACTICES
IN THE HANDLING OF DAIRY PLANT WASTES

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CURRENT PRACTICES IN THE HANDLING OF DAIRY WASTES

A paper prepared for presentation in the session on treatment for the U. S. Environmental Protection Agency Technology Trasnfer Seminar for the dairy industry.

Kenneth S. Watson
Director of Environmental Control
Kraftco Corporation
Glenview, Illinois

The laws, regulations guidelines and thus particularly the pollution control efforts necessary in the dairy industry are rapidly evolving so it is highly desirable to orient plant management and production people with what is going on. For these reasons this technology transfer seminar for the industry should be beneficial. We are happy to have the opportunity to participate in this seminar and hope that jointly we can make it fully productive.

The treatment approaches and methods which have application to dairy wastes are areas of significance to those who must operate plants today. For these reasons this portion of the seminar will be concerned with the treatment portion of the problem.

In addition to hearing from four speakers on various aspects of treatment you will be supplied a brochure covering these presentations and some reprints on foreign practice. The reprints briefly cover treatment activities at dairy plants in Canada, England, New Zealand, Finland, Czechoslovakia, Denmark and Germany.

The Dairy Wastes Situation

The dairy industry is made up of a large number of, for the most part, relatively small plants scattered primarily through the milk producing sections of the nation. These plants range from single product milk processing or cheese plants to rather complex multi-product facilities in which milk, cottage cheese, sour cream, ice cream, yogurt, etc., may, for instance, be produced.

Since many of the plants are small and located adjacent to municipalities the usual practice has been to connect these plants into municipal sewer systems. In fact almost 90% of the plants dispose of their wastes in this manner.

Another reason for this method of waste disposal is the fact that for the most part dairy plant wastes are biodegradable and compatible with the wastewater present in a municipal system. Even fats, oils and greases present in dairy plant wastes are edible and biodegradable so municipalities need not feel the same concern for these materials as is the case with the same constituents of petroleum origin. Since the average size of the dairy plant rules against its being able to afford or professionally operate a pretreatment facility the industry as a general rule would prefer to buy this sewerage service from the City.

As has already been covered, but it probably deserves mentioning here again in the interest of completeness for this session, plant people should exhaust the in-plant, short-of-treatment approach as the soundest and simplest method of controlling a waste problem. In addition

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to coming to grips with the pollution problem such action will also result in cost reductions through improved production efficiencies, reductions in losses and reductions in water usage.

Character of the Wastes

Further, as has been touched upon by other speakers, dairy plant wastes consist mainly of lost raw materials, intermediate and finished products and the cleaning materials required to clean and sanitize shipping containers and processing space and equipment all carried in the process waters being discharged by the plant. In addition, whey is a byproduct of most cheese operations and can become a significant pollution problem. Every effort should be made to keep it out of the sewer system when it can readily be separated from the water being used in the plant. The usual procedure is to concentrate the whey so it can be dried to whey powder or converted into another usable byproduct either at the plant produced or at another location which can economically be reached from the point of production. These whey byproducts are then used as food or feed supplements. Whey is of sufficient significance that it will again be considered under Irrigation.

Milk plant wastes normally have a BOD concentration ranging roughly between 500 and 4000 mg/1 and a COD concentration which usually runs 2 to 2.5 times higher. As a general rule the suspended solids in such wastes are not high enough to be of great significance. Cleaning compounds being used, particularly in larger plants, can be responsible for swings of consequence in the pH of the effluent but these can normally be satisfactorily corrected by equalization by the City or the

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plant generating the wastes.

Disposing of the Effluent

The various methods of disposing of dairy plant effluents will next be briefly considered.

Biological Treatment

Most dairy plant wastes respond to the biological treatment approach. The wastes are similar to municipal wastewater but considerably more concentrated and more readily degraded. Since the biological treatment approach most generally represents the best and most economical method of treating dairy wastes to reduce the BOD and COD concentrations to acceptable ones, it will be given consideration in this and the other presentations in this session. Since biological treatment of dairy wastes is widely provided in municipal treatment systems, one of the papers will be devoted to this special subject.

A second paper will be the story of how a dairy plant uses the biological approach to treat its wastes for stream discharge.

Irrigation

Irrigation of the process wastes as a means of disposal is a viable approach for some dairy plants. The common methods of irrigation are: spray fields, spreading and ridge and furrow application. The plant has to own adequate land or have it under lease of suitable type to take the volume of wastewater to be disposed of without runoff into the streams of the area. Further, the irrigation land must be close enough so it can be reached by pipeline or truck on an economical basis.

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Some isolation is necessary for a satisfactory irrigation site so no odor nuisance conditions will be created. Further, care must be exercised in application so ponding on the land does not take place.

Irrigation works best in areas where the winter climate is not severe but can be used in such wintry areas if properly operated. Some lagoon holding space, in some cases with the use of aeration, is desirable in conjunction with the operation of irrigation projects to provide holding flexibility for rainy or wintry periods.

Spreading on land represents another method of discarding whey for certain types of plants. There are a significant number of small cheese plants which are somewhat isolated and cannot afford concentration equipment and stay in operation. Further, as a result of the volume of whey produced and the scatter of the plants in the particular region central drying facilities cannot be justified.

Under these conditions, in order for these plants with their vital cheese production to remain in operation, land disposal of the whey must be practiced. In many areas a mutually beneficial arrangement has been worked out with the farmers in the immediate vicinity of the plant to dispose of the whey on their farms to take advantage of the nutritional value to benefit the land.

Acknowledgements

The author wishes to express appreciation for the diligent efforts of representatives of the Environmental Laboratory, the plants and their Divisions for developing the data and assembling it, and for providing counsel in the preparation of the paper.

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TREATMENT PRACTICES IN KRAFTCO

STOCKTON, ILLINOIS

The Kraft Foods Division facility at Stockton, Illinois consists of two separate operating plants - one for the manufacturing of bulk Swiss cheese and the other for processing whey. All of the whey from the cheese operation is condensed at the whey plant with the majority of it being spray dried along with condensed whey received from other Kraft manufacturing facilities in the area. The balance of the whey is processed into several other institutional and industrial products. The cheese plant is shown in Figure 1.

As is indicated in Table 1, the wastewater volume has increased at Stockton from about 86,000 gpd in 1968 to 110,000 gpd at present. Over this same period, however, the BOD load leaving the plant has been reduced from 1950 to 900 pounds per day by in-plant process modifications and improved housekeeping.

The existing waste treatment system has evolved over the almost 60 years that the plant has been in operation through efforts to solve the wastes problem in the simplest and most economical manner. Summer operation consists of pumping the total plant discharge through the irrigation system on site summarized in Table 2. The concept here is through the use of automatic controls to rotate the dosing of the land through a preplanned application cycle so overdosing does not occur at any one location and a maximum of percolation, evaporation and transpiration of moisture will occur. Thirty-two nozzles are installed on site, each having a capacity of 90 gpm, and dose in rotation. Each has the ability to spray roughly an acre. By the use of this approach maximum advantage is being taken of the land and its cover crop to absorb the total plant discharge.

In the winter time an activated sludge system is used the basin for which is shown in Figures 2 and 3. A summary of information on the activated sludge system is shown in Table 3. The basin is operated using diffused air from a bottom diffuser normally supplemented by two floating aerators. The discharge from the basin is passed through a clarifier (Fig. 3A). From the clarifier, final disposal is made to a ridge and furrow system on site. This system is on contour with an overflow of the control gate of one trench to the adjoining trench below. More details are supplied in Table 3.

The usable volume of the basin is 570,000 gallons having a detention time of 5 days. It is loaded at about 24 pounds of BOD per thousand cubic feet. When sludge must be removed from the system it is drawn from the clarifier to a sludge lagoon located nearby. Sludge is removed from the lagoon once a year in the spring and spread on adjoining grass land.

For the plant to discharge into the small stream to which it is tributary and meet the very stringent requirements of the Illinois EPA, the effluent concentration would have to be less than 5 mg/l of BOD and 4 mg/l of suspended solids. The decision was therefore reached that necessary facilities should be installed to retain the effluent on site and depend upon evaporation and percolation for disposal. For these reasons two impoundment and flood control ponds were located at the lowest point on the property. These lagoons of 3,100,000 and 4,250,000 gallons capacity were provided to catch any runoff from the site during either summer or winter operations. One of these ponds is shown in Figure 4.

In relating how this plant solved its problem, the point should be made that the solution has been tailored through evolution to this particular plant's waste load in the particular habitat where located. Many processes are in use here, however, which could have application to other dairy plant wastes. The soundest and most economical solution to a plant problem, however, will always be arrived at by tailoring the treatment to the particular situation in question.

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Table 1

Waste Load Being Discharged by Stockton Plant *

	WHEY PLANT		CHEESE PLANT		TOTAL	
	1968-9	1972	1968-9	1972	1968-9	1972
Volume gpd	57,000	80,000	29,000	29,000	86,000	110,000
BOD mg/l	2,900	900	2,400	800	2,700	870
BOD Load lb/Day	1,370	600	580	300	1,950	900

* Significant reduction in the BOD load due to in-plant processing modifications and improved housekeeping.

Table 2

The Kraft Foods Irrigation System at Stockton

SPRAY FIELD

50 acres of moderately sloping ground

32 operating sprayheads + 2 standby

Volume - 90 gpm (each)

Coverage - 220 ft. diameter circle (approximately 1 acre)

MODE OF OPERATION

Automatic

16 circuits - 2 sprayheads/circuit

Rotates through 16 positions

Preset at 90 minutes per position

Mowed - every 3-4 weeks with 6 foot chopper mower

Table 3

The Winter System for Handling Effluent at Stockton

Activated Sludge Plant

Aeration basin: 212' x 68' x 10'

Aerators - 3 - 40 HP blowers each delivering 400 scfm @ 4.5 psig
2 floating aerators

Volume - 570,000 gallons

Capacity - about 1.3 lbs. O_2/lb BOD applied

Clarifier: 24' diameter x 9' SWD - 1/2 HP sludge rake

Volume - 30,000 gallons

Detention - 7.2 hrs.

Sludge Lagoon: 100' x 40' x 10'

Volume - 300,000 gals.

Supernatant fed back to aeration basin

Ridge and Furrow System

10,000 lineal feet on contour

18" deep by 4' wide furrow (trench) separated on 12' centers by ridge

Overflow control gates at ends of adjoining trenches

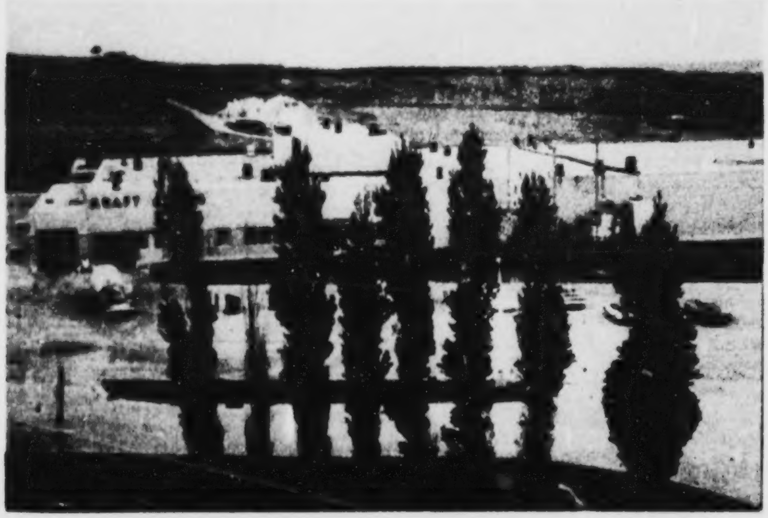

FIGURE 1 - The cheese plant at Stockton, Illinois with spray fields in background.

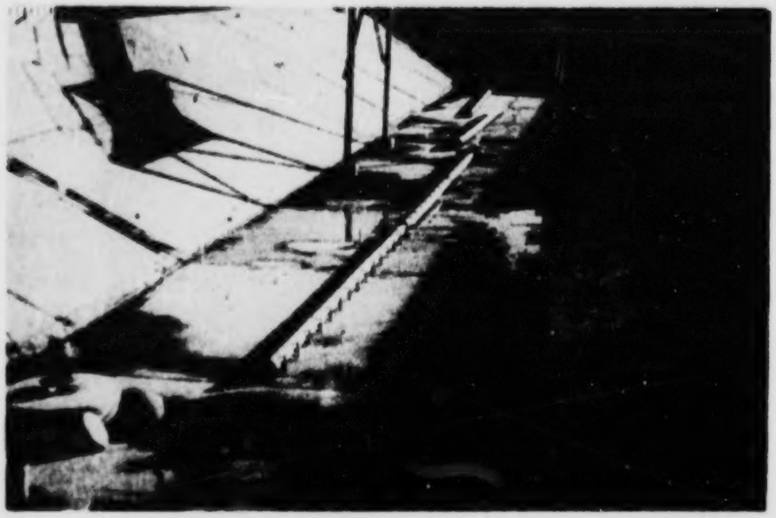

FIGURE 2 - Aeration basin, air diffusion piping and floating aerators.

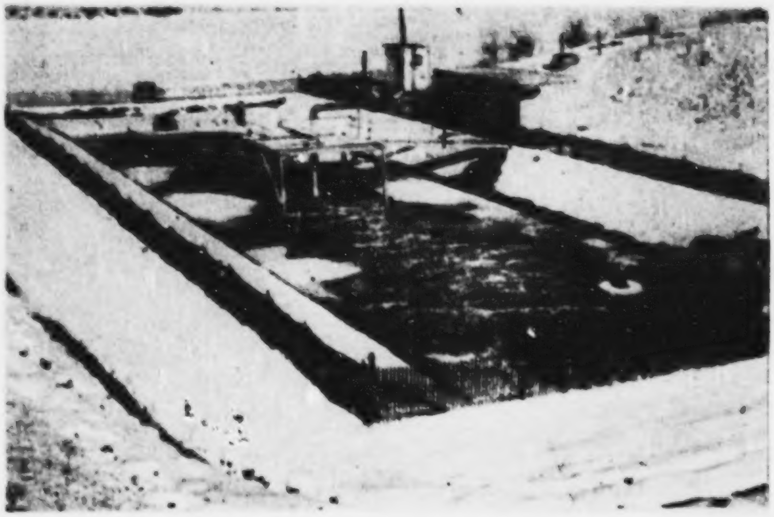

FIGURE 3 - Aeration basin - winter operation.

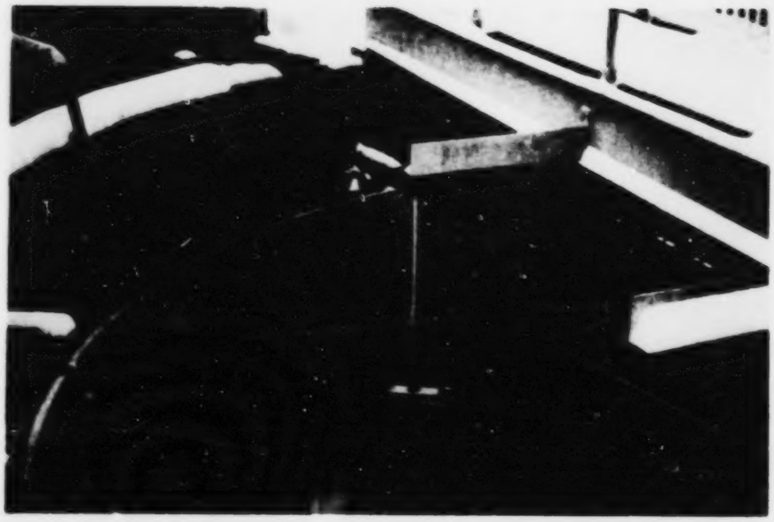

FIGURE 3A - The Stockton clarifier.

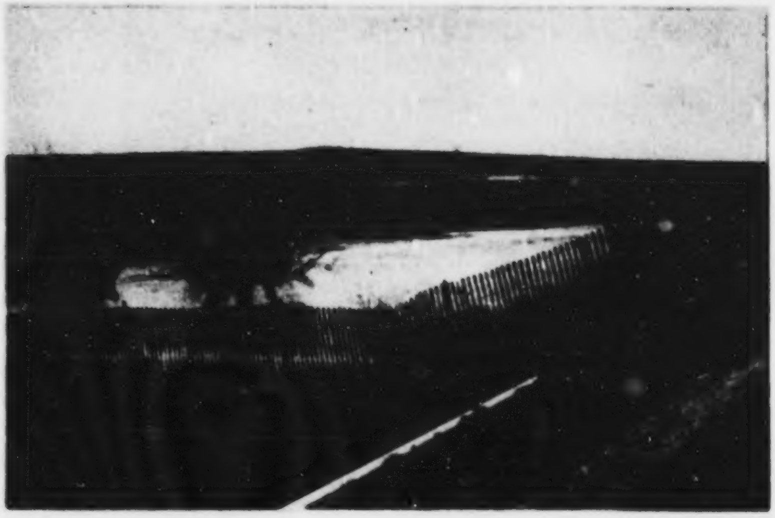

FIGURE 4 - Impounding and flood control pond.

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NORWICH, NEW YORK

Coverage of this plant is included in this summary paper because its treatment plant is new and of the biological type which is widely used in the handling of dairy plant wastes. This Sheffield Chemical manufacturing facility is not a typical dairy plant, but its principal raw material is whey concentrated to 50% solids. Among the major products manufactured by this Norwich facility: are lactose, calcium lactate, sodium caseinate and food flavorings.

When it became apparent that the lagoon system being used at Norwich would have to be replaced by more efficient treatment facilities, agreement was reached with the State of New York that some pilot scale work should be done to provide the basis of design for the new treatment facilities. Consequently, a biological pilot scale unit was designed and placed in operation in October 1970. The pilot facility shown in the foreground of Figure 5 was, and can still be, operated on a side stream of the discharge from the manufacturing plant. The activated sludge facility for this pilot unit, operated on diffused air, is shown in the background with the round final clarifier shown in the foreground.

The pilot facility was operated for about nine months under laboratory control. During this same period, the design of the full scale treatment facility was moved forward as was a program of in-plant, short-of-treatment steps to better manage water and reduce the waste load. Construction of the waste treatment facility was started in July, 1971 and it was placed in operation in February, 1972.

The full scale facility consists of an activated sludge basin broken into three compartments shown in the background of Figure 5, in which the flexibility has been incorporated to permit it to be operated using either the contact stabilization or extended aeration mode. The biological treatment basin is followed by a final clarification stage consisting of the two clarifiers shown in Figure 6. Alum is fed to the aeration basin effluent to improve the flocculation in the final clarifier. When sludge must be drawn from the system, it is removed from the clarifier to a sludge tank to be scavenged from the site. Figure 7 shows the control building in which pumps, blowers, the flow recorder and the laboratory are located. A picture of the laboratory is shown in Figure 8.

The treatment facility was designed to handle a hydraulic loading of 250,000 gallons per day and a BOD load of 2500 pounds per day with 90% removal of BOD anticipated. A maximum retention time of 3.2 days was provided in the aeration basins. Additional information on sizes and specifications of equipment is shown in Table 4. Since the level of suspended solids in the manufacturing plant effluent did not appear of great significance, no primary treatment was incorporated in the system. Since the need for feeding nutrients to improve the operation of the system had not been established prior to its being placed in operation ammonia is being fed on an improvised basis into the influent end of the aeration basin. Since the use of ammonia is beneficial, facilities are being added to the system to permit ammonia to be fed on a permanent basis.

The concept in use at this plant is to completely separate the process wastes from the cooling water so the former can be put through the treatment plant and the latter by-passed around same. Thus, sampling locations have been provided for ahead of, and following, the treatment facilities. Finally, a sampling and measuring station has been provided for monitoring the combined process and cooling water waste stream which flows into the river.

Some feel for the operation of the treatment facilities can be obtained by reviewing Tables 5 and 6. Operating experience, to date, indicates that the 90% reduction in BOD for which the system was designed can generally be met. As, is borne out by low minimum effluent, concentrations shown in Table 6, at times the system does go above 90% efficiency in removal of BOD. Operating experience has further demonstrated that the extended aeration mode of operation produces considerably better results than does contact stabilization.

A program of relating river conditions to treatment plant operation has been launched and will be expanded. An initial look at river conditions, on the basis of dissolved oxygen, is shown in Table 7. It will be noted that as a general rule the dissolved oxygen in the stream is higher below the plant discharge than it is above.

Just recently, the pilot facility was placed back in operation to develop a better feel for how to upgrade the performance of the full-scale unit.

Table 4

Sizes and Specifications of Waste Treatment Facilities at Sheffield Chemical, Norwich

Aeration Facility

1. 3 tanks each 160 ft. long, 16 ft. wide, 11 ft. liquid depth, 28160 cu. ft. volume.

2. Loading - 30# BOD per 1000 cu. ft. of aeration tank volume.

Air

1. 1.5# O_2per #BOd design.

2. 3 blowers each 40 hp., 1200 cfm.

3. 300 coarse bubble air diffusers.

Settling Tank

1. 17 ft. diameter, 3600 cu. ft. volume.

2. Retention time 2.9 hours at 1.1 mgd.

Table 5

Mean Results Obtained From the Sheffield Chemical Treatment Facility at Norwich*

Week	Flow	BOD mg/l		COD mg/l		pH
Ending	GPD	Influent	Effluent	Influent	Effluent	Influent
10/6/72	171040	907	80	33281	369	7.4
10/13	222860	1200	54	3104	754	7.8
10/20	185780	1276	62	3047	241	7.1
10/27	153200	1983	52	4075	70	6.2
11/3	180933	1639	94	5425	312	7.4
11/10	146120	1570	18	1588	433	6.4
11/17	169920	1023	21	2533	61	6.2
11/24	154480	871	21	2945	74	6.5
12/1	138140	1895	9	5307	170	5.0

* Based on daily analyses (5-day week) of representative composite samples

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Table 6

BOD Results Obtained from the Sheffield Chemical Treatment Facility at Norwich*

Week Ending	Influent mg/l		Effluent mg/l	
	Max.	Min.	Max.	Min.
10/6/72	1608	257	142	16
10/13	2248	791	74	21
10/20	1570	778	101	15
10/27	3621	1248	75	29
11/3	2231	1253	189	16
11/10	2873	832	24	12
11/17	1279	832	40	4
11/24	1005	736	31	12
12/1	2196	1475	18	3

* Based on daily analyses (5-day week) representative composite samples

Table 7

Dissolved Oxygen Conditions in the River Receiving the Discharge from the Sheffield Chemical Treatment Facility at Norwich*

Week Ending	Above D.O. mg/l	Below D.O. mg/l
10/6/72	8.8	9.4
10/13	9.4	9.8
10/20	9.9	10.2
10/27	9.7	10.1
11/3	10.1	10.7
11/10	9.0	10.3
11/17	10.9	11.5
11/24	10.5	10.4
12/1	12.7	13.0

* Based on daily analyses (5-day week) of grade samples

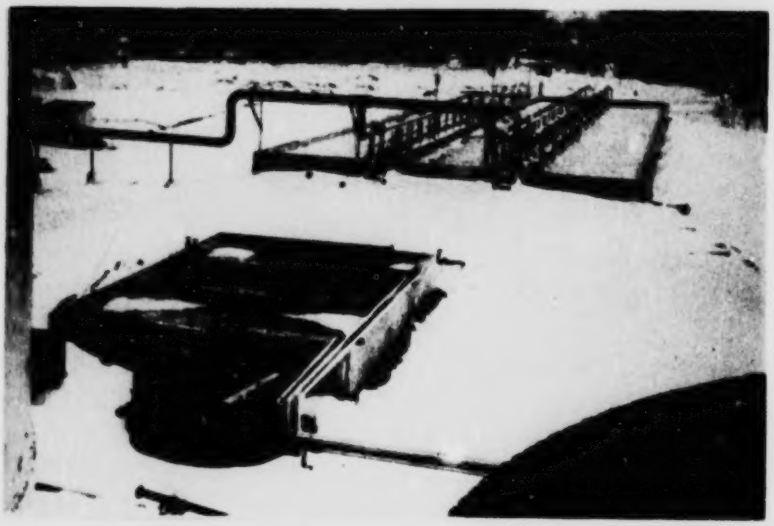

FIGURE 5 - Pilot plant facility in foreground - aeration basin of main treatment facility in background.

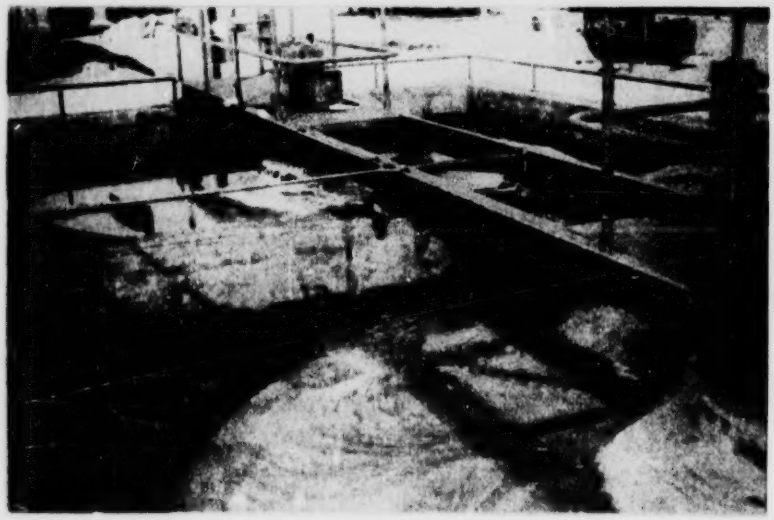

FIGURE 6 - The two tank final clarification stage.

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FIGURE 7 - The control building.

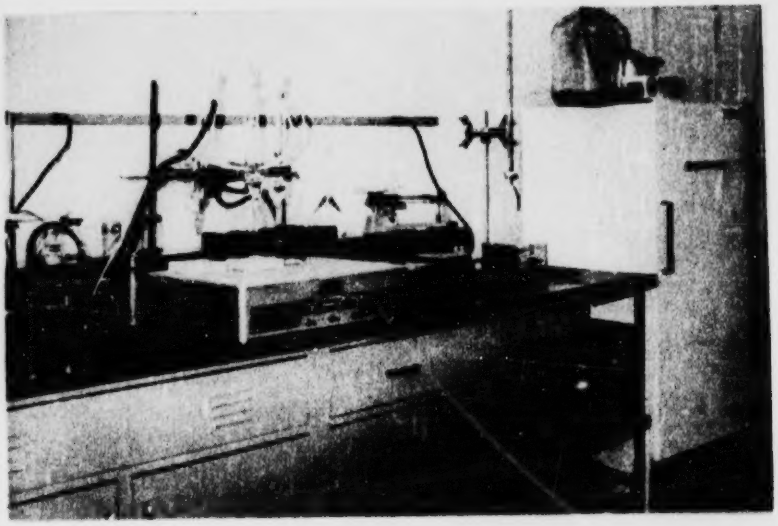

FIGURE 8 - The wastewater laboratory in the control building.

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SOUTH EDMESTON, NEW YORK

This plant of the Breakstone Sugar Creek Foods Division produces yogurt and ricotta cheese. The plant effluent is treated on site and discharged into the stream.

The wastewater effluent from the processing plant is perhaps somewhat lower in concentration than is the case with that from many dairy plants. From Table 8 it is apparent that the average BOD concentration is 485 mg/l and the suspended solids 147 mg/l. As is indicated by the analytical characteristics, every effort is made to keep whey out of the plant discharge.

The effluent treatment system consists of a raw wastes pumping station, aerated lagoon, clarifier, sludge basin and chlorinator. A flow diagram of the system is shown in Figure 9. The aeration lagoon is shown in Figure 10 and one end of the clarifier at the edge of the basin can be seen in this Figure. In the center of the aeration basin is located a 20 H.P. high-speed floating aerator shown in Figure 11.

After biological treatment in the lagoon the effluent enters a tank which is divided into two compartments and passes through the clarifier section, with a 2.5 hour holding capacity, which is served by a sludge raking flight. The remainder of the tank consists of a compartment for holding sludge which is removed from the effluent by the clarifier. This sludge is returned to the aeration basin through the use of a sludge sump and pump located adjacent to the tank. The effluent is chlorinated at the flow measuring device to comply with State requirements because it also carries the sanitary discharge from the plant.

The treatment facility was designed for a BOD loading of 560 pounds per day and an effluent volume of 172,000 gpd. The design called for removing 85% of the BOD and 90% of the suspended solids. As shown by figures listed in Table 8, the treatment facilities are at present somewhat underloaded. The removal of BOD is averaging about 95% (Table 9). The removal of suspended solids is somewhat less efficient perhaps because the concentration is not high to start with. In both cases effluent concentrations fall well within State specifications.

As a result of operating experience the aerator, which was sized to provide 1.5 pounds of oxygen per pound of BOD, is controlled by a timer. It is in operation about 66% of the time which keeps the dissolved oxygen content of the basin between 5 - 6 mg/l. Such an operating mode provides expansion capacity in the treatment facilities and tends to improve sludge settleability over higher oxygen concentrations being maintained in the basin.

Provisions have been made in this system for adequate sampling and analyses to control its operation. The treatment plant influent is sampled in a representative manner through a valve on the discharge side of the pump delivering all the wastewater to the system. As the effluent leaves the clarifier, the flow is recorded and totalized using the Kenneson nozzle shown in Figure 12. The flow recorder is shown in Figure 13.

Figure 14 shows the laboratory which handles the wastewater analyses for this plant and another located nearby. It is located within the process plant. Tests which are run include BOD , COD, suspended solids, total solids and volatile suspended and total solids. Operational tests for controlling the treatment system consist of dissolved oxygen, mixed liquor suspended solids, settleable solids and chlorine residual.

Table 8

Condensed Summary of Monthly Averages of the Influent to the South Edmeston Treatment Facility

	Avg. Max.	Avg. Min.	Avg.	Avg. lbs/day
BOD mg/l	552	408	485	440
COD mg/l	1033	955	1010	916
Suspended solids	208	128	162	147
Flow gal/day	142,758	73,880	108,778	

Table 9

Condensed Summary of Monthly Averages of the Effluent of the South Edmeston Treatment Facility

	Avg. Max.	Avg. Min.	Avg.	Avg. lbs/day
BOD mg/l	31.8	11.5	20.8	18.9
COD mg/l	68	25	47.9	43.5
Suspended solids	56	17	32	29
Flow gal/day	142,758	73,880	108,778	

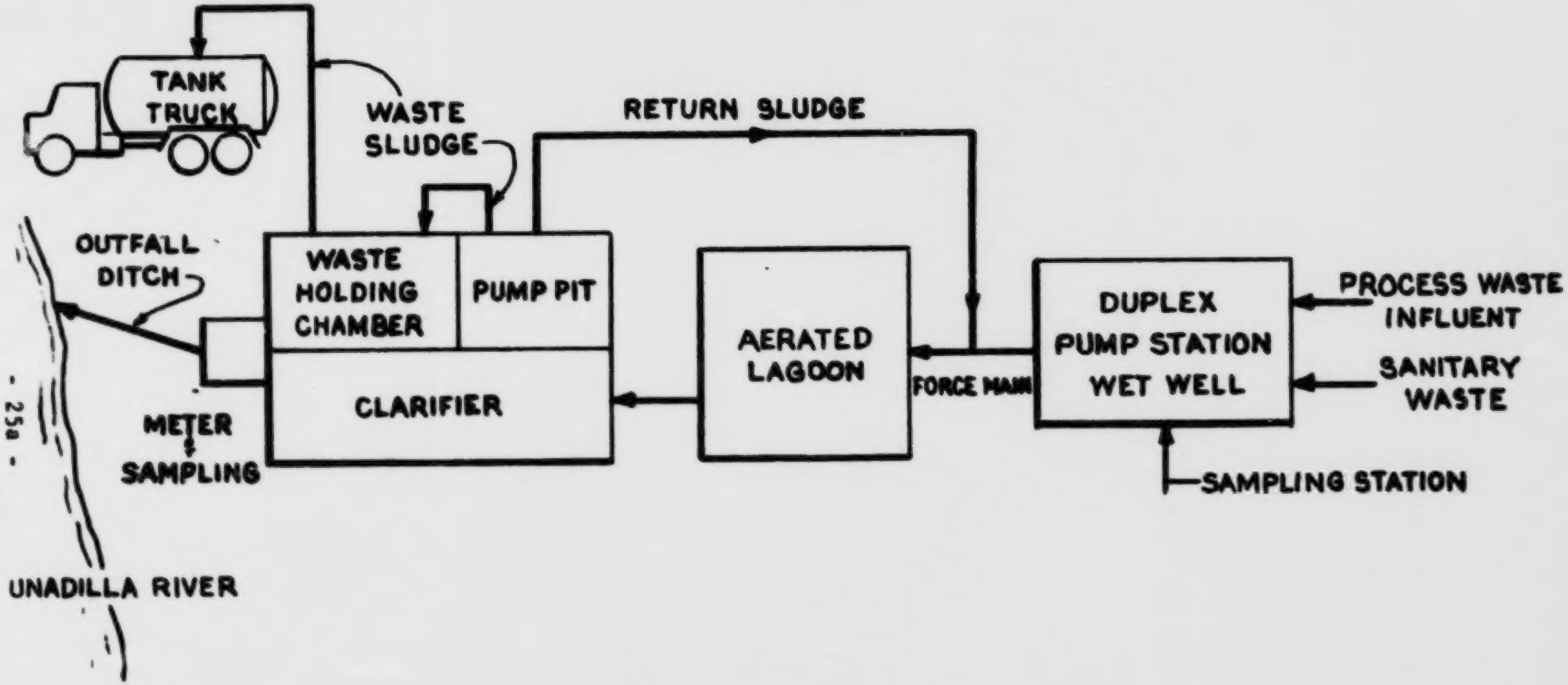
TANK TRUCK
WASTE SLUDGE
RETURN SLUDGE
OUTFALL DITCH
WASTE HOLDING CHAMBER
PUMP PIT
CLARIFIER
AERATED LAGOON
FORCE MAIN
DUPLEX PUMP STATION WET WELL
PROCESS WASTE INFLUENT
SANITARY WASTE
SAMPLING STATION
METER & SAMPLING
UNADILLA RIVER

Fig. 9

TREATMENT FACILITIES - SOUTH EDMESTON PLANT

BREAKSTONE - SUGAR CREEK DIV.

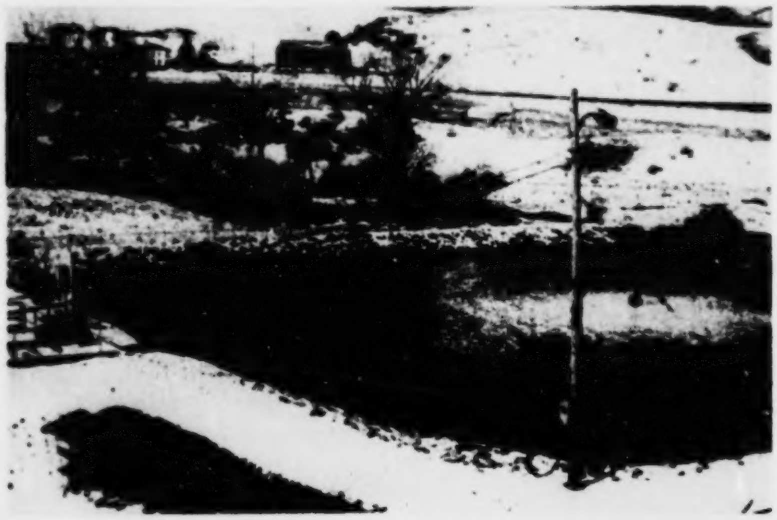

FIGURE 10 - Aerated lagoon - South Edmeston.

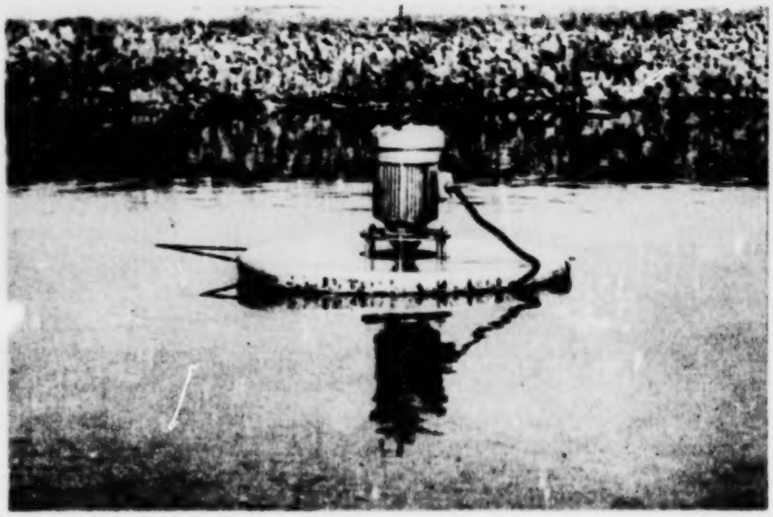

FIGURE 11 - Floating aerator - South Edmeston.

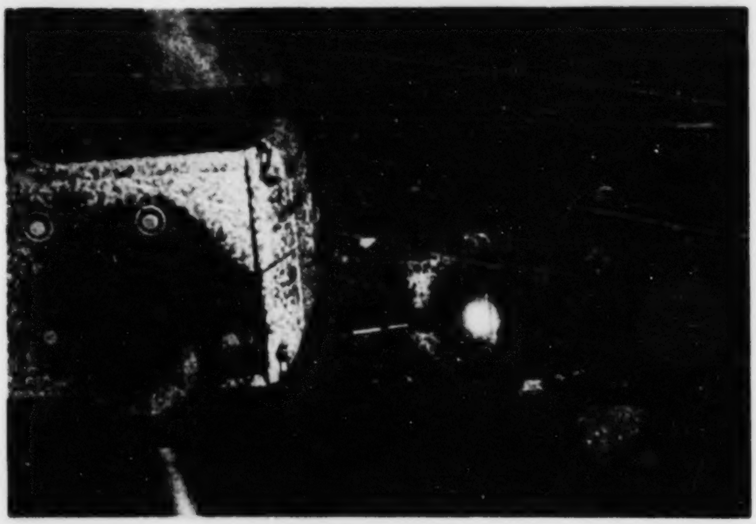

FIGURE 12 - Kenneson nozzle measuring final effluent.

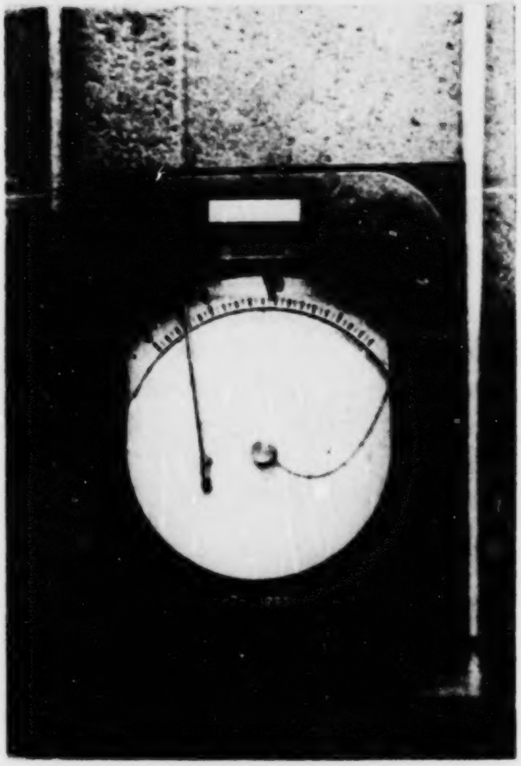

FIGURE 13 - Recorder final effluent.

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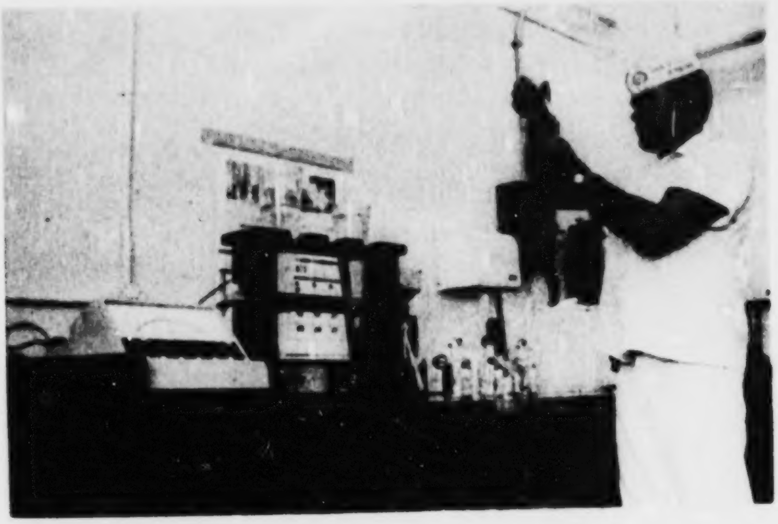

FIGURE 14 - Wastewater laboratory in quality control laboratory.

CHAMPAIGN, ILLINOIS

Kraft Foods has had a margarine and salad dressings plant in operation in Champaign since the early 1960 period. In 1968 the decision was reached to make a major expansion at the Champaign plant.

Kraft Foods' present production facility is shown in Figure 15. In the foreground the right hand portion of the facility is in general the original oil plant in which margarine, salad dressings and oil products are manufactured. The left portion of the facility is new, having been placed in operation over a year ago and in which macaroni type products, process cheeses (slices and Velveeta type) and natural cheeses in consumer size packages are produced. The plant immediately behind the Kraft plant on the right is an edible oil refinery operated by the HumKo Operation of the Corporation. It should be noted that the close proximity of these facilities to extensive residential areas means that all phases of environmental control must be carefully practiced.

Waste Treatment - In planning for the plant expansion, early consideration was given to proper handling of the liquid wastes problem for the expanded facility. As is the Corporation's usual approach, it was proposed to the Urbana-Champaign Sanitary District that the District provide sewerage service for the expanded plant at Kraft's expense since the wastes to be discharged would be completely compatible with District wastewater and be degraded in its professionally operated treatment system. After considerable negotiation the District stood fast on its position that it could accept the hydraulic load but the plant would need to provide treatment facilities to meet the specification of: 200 mg/l of BOD, 200 mg/l of suspended solids and 100 mg/l of fats, oils and greases covered in a proposed ordinance.

Since business considerations dictated that the production capacities and mix of products already mentioned should be located at Champaign, the only course open was to provide the same type of biological treatment facilities as those operated by the District. These facilities of course must be operated from now on. The pretreatment facility provided is shown at the left rear of the site (Figure 15).

As a result of the configuration of the site it was necessary to separate the primary facilities from the secondary. The design basis for the plant is shown in Table 10. It will be noted that the facility has been designed for a projected 1980 load.

The wastes from the cheese and oil production facilities at Champaign are collected in lift stations and pumped to a surge tank. The items of equipment used in the treatment system are summarized in Table 11. The major units in the primary plant are shown in Figure 16. The surge tank is on the left with the pump house in the center and sludge storage (not presently being used) and grease storage tanks on the right. The next step in the process is the flotation clarifier shown in Figure 17. Grease skimmed from the surface of this unit is conveyed to the grease tank already mentioned. The sludge removed from the clarifier is passed on to the aeration basin to avoid the need for primary sludge handling facilities.

Next, the effluent flows to the aeration basin, the first step in the secondary treatment portion of the system, shown in Figure 18. The discharge from the aeration basin then passes through the final clarifier and into the District system.

Controlling Operations - Arrangements have been made for collecting samples at various points throughout the system. An automatic, composite sampler is located on the final discharge so a continuous record can be developed on the load being contributed to the District. Laboratory control results for the operation of these treatment facilities are run in the quality control laboratory. Figure 19 shows a temporary laboratory setup within the pump house in which emulsion breaking studies were carried out.

Table 12 shows the quality of the effluent being discharged into the Sanitary District system at Champaign from the middle of December 1972 until the end of January 1973 based on daily analyses. Unfortunately the plant decided to make some changes in its sampling and analytical regime in October and had not again started running BOD analyses on the influent to the plant during the period under consideration. The monthly maximum, minimum and mean BOD results on the influent for a three-month period ending with October were respectively 5268, 1113 and 3223 mg/l. Thus if the influent BOD had remained in the same general range for the six-week period under consideration, BOD reductions would have ranged between roughly 90 and 98%. It is apparent from Table 12 that the reduction in suspended solids resulting from passing the effluent through the plant ranged between 85.6 and 95.9%. Further the COD reduction ranged between 93 and 97.4%.

Since the more work we do in Kraftco on the degrading of edible fats, oils and greases in a plant effluent the clearer it becomes that these types of materials are rather readily degradable in biological treatment systems, as one would expect, this paper will be concluded by looking briefly at this situation at Champaign. Table 13 summarizes the concentration of fats, oils and greases on a monthly basis in the influent and effluent of the treatment plant for the last six months of 1972. The reductions from influent to effluent across the system are accomplished by a combination of the primary and secondary treatment processes in use. It is of interest to note that an average of 97.4% of the fats, oils and greases were removed or degraded by the treatment system described.

Table 10

Kraft Foods
Champaign, Illinois

BASIS OF DESIGN FOR 1980 LOAD

Parameters	Design
Average Flow gpd	500,000
gpm	350
BOD mg/l	3,640
BOD Load lb/day	15,000
Suspended Solids mg/l	685
Suspended Solids lb/day	2,850
Grease mg/l	3,140
Grease lb/day	13,000

Table 11

Kraft Foods
Champaign, Illinois

ITEMS OF EQUIPMENT IN THE TREATMENT SYSTEM

PRIMARY PLANT

Lift Stations

Cheese - 2 - 225 gpm - 10.0 H.P. Pumps
Oil Plant - 2 - 250 gpm - 7.5 H.P. Pumps

Surge Tank

1 - 30'D x 20'H - 80,000 gal. with 10 H.P. agitator and sludge rake
Minimum Detention Time - 1.5 hours (avg. flow and 6' level)
Max. Detention Time - 4.5 hours (avg. flow - 18' level)

Flotation Clarifier

1 - 39'D x 10'H - 76,000 gal. with sludge rakes and surface skimmer and recycle pressurization system.
At 50% recycle and avg. flow - surface settling rate = 625 gpd/ft^2
Weir overflow rate - 2450 gpd/lineal ft.; detention time = 2.45 hrs.

Primary Sludge Storage Tank

1 - 30'D x 9'-6"H Covered Tank - 42,500 gal.

Grease Storage Tank

1 - 14'D x 29'H Cone Bottom, covered, heated tank - 18,000 gal.

Table 11 (cont.)

Kraft Foods, Champaign, Illinois
Items of Equipment in the Treatment System

SECONDARY PLANT

Aeration Basin

Rectangular Basin 309 x 149 x 9' Deep
Operation Volume - 2,270,000 Gal.
Detention Time @ avg. flow - 4.5 days

Dorr-Inka Aeration system using 4-75 HP blowers @ 8,000 scfm each

Final Clarifier

1 - 49'D x 8½'H tank - 100,000 gal. with sludge rakes and surface skimmers

At avg. flow - Surface settling rate = 270 gpd/ft^2
Weir overflow rate = 325 gpd/lineal ft
Detention time = 4.8 hours

Aerobic Digestor

1 - 50'D x 27'H tank - 368,000 gal. with
3 - 50 H.P. Blowers - 700 scfm @ 7.5 Psig each

Sludge Lagoons (located at Sanitary District's plant site)

2 - 1 acre surface x 8'D earthen tanks

Table 12

The Effluent Being Discharged into the System
Kraft Foods, Champaign, Illinois District

	FLOW mgd	BOD mg/1			COD mg/1	SS mg/1
	Mean	Max	Min	Mean	Mean	Mean
Dec. 15-21, 1972						
Influent	0.283	-	-	-	4397	1036
Effluent		90	45	54	157	61
% Removal					96.4	94.1
Dec. 22-28						
Influent	0.210	-	-	-	5176	1200
Effluent		221	74	125	376	93
% Removal					92.7	92.2
Jan. 1-7, 1973						
Influent	0.233	-	-	-	5157	1244
Effluent		113	32	73	254	92
% Removal					95.1	92.6
Jan. 8-14						
Influent	0.269	-	-	-	7471	1807
Effluent		82	32	58	192	74
% Removal					97.4	95.9
Jan. 15-21						
Influent	0.262	-	-	-	5434	1210
Effluent		214	54	127	337	97
% Removal					93.8	92.0
Jan. 22-28						
Influent	0.280	-	-	-	6225	1368
Effluent		142	99	117	438	184
% Removal					93.0	86.5

Table 13

Removal of Fats, Oils and Greases by the Champaign Treatment Plant of Kraft Foods, 1972

MONTH	INFLUENT mg/1			EFFLUENT mg/1			% REMOVAL
	Max.	Min.	Mean	Max.	Min.	Mean	$\% = (100)\ \frac{\text{Inf.(Mean)}-\text{Eff.(Mean)}}{\text{Inf. (Mean)}}$
July	2,780	161	1,376	98	29	47	96.6
Aug.	9,023	494	1,945	57	25	35	98.2
Sept.	1,966	416	1,176	50	27	39	96.7
Oct.	2,845	181	1,134	111	15	41	96.4
Nov.	4,002	215	1,058	108	6	21	98.0
Dec.	2,314	243	1,158	47	4	17	98.5
TOTAL	22,930	1,710	7,847	472	106	200	584.4
AVERAGE	3,822	285	1,308	79	18	33	97.4

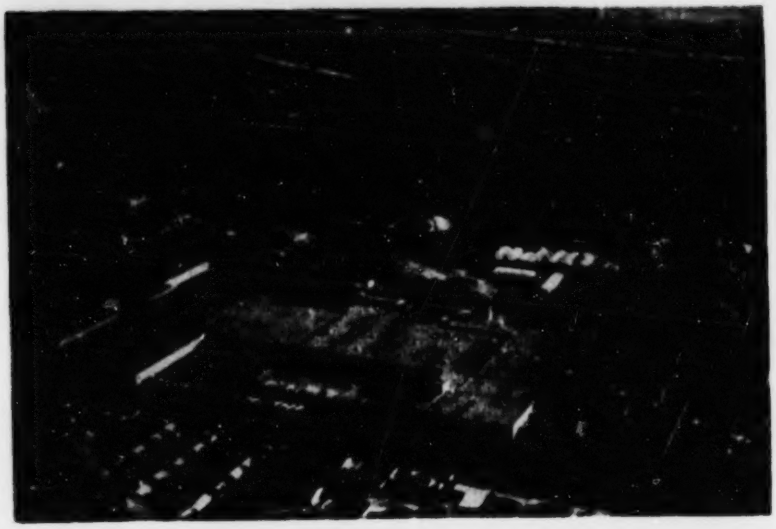

FIGURE 15 - Aerial view of Kraft Foods plant and surroundings.

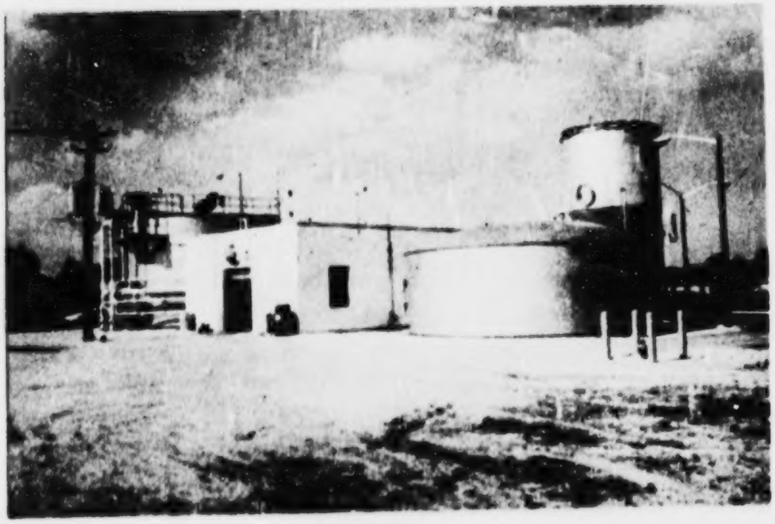

FIGURE 16 - Primary plant (L to R) surge tank, pump house, primary sludge storage tank, grease storage tank.

FIGURE 17 - Flotation-clarifier, scum skimmer at 9 o'clock.

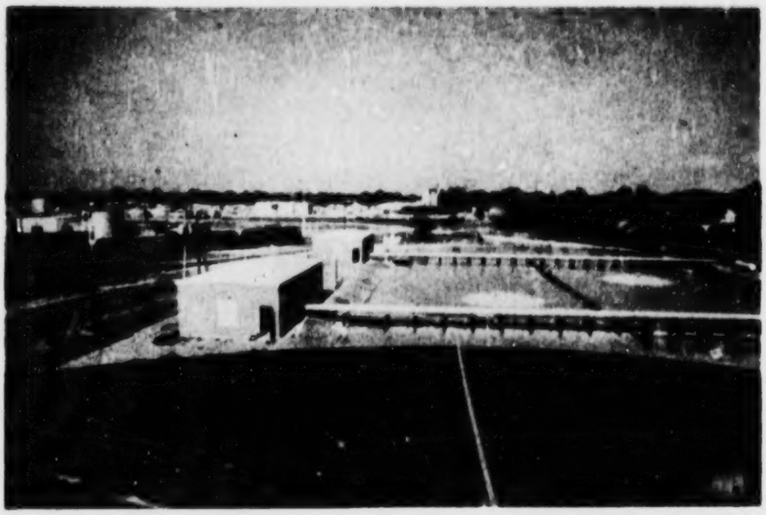

FIGURE 18 - Aeration basin, blower houses and air piping - primary plant at left, beyond railroad cars.

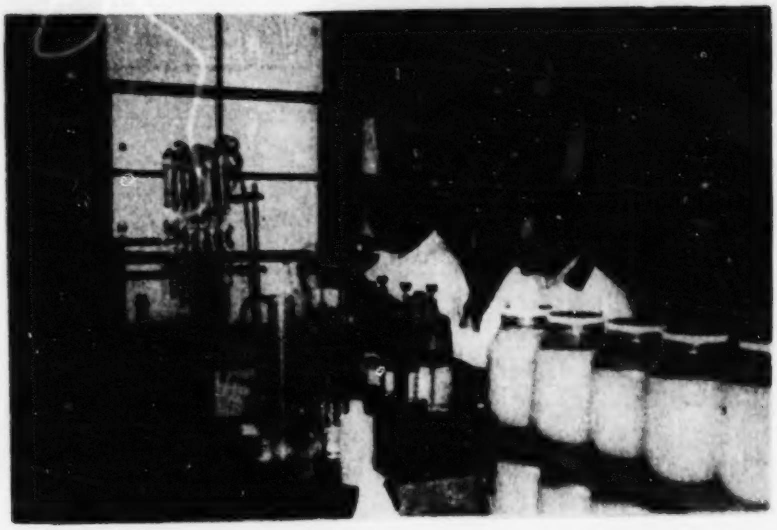

FIGURE 19 - Inside pump house - emulsion breaking tests - temporary laboratory setup for F.O.G.

THE BENEFITS OF THE JOINT TREATMENT APPROACH WITH THE CITY

Paul T. Hickman, P.E.
Hood-Rich
Architects and Consulting Engineers
Springfield, Missouri

Presented at an Environmental
Protection Agency Technology Transfer
Seminar for Dairy Industries
March 20 & 21, 1973, Madison, Wisconsin

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THE BENEFITS OF THE JOINT TREATMENT APPROACH WITH THE CITY

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INTRODUCTION:

This presentation is a case history showing the joint municipal and industrial approach to water pollution control as practiced in the City of Springfield, Missouri over the past ten (10) years. While it must be recognized that each city and its industries are different in many respects, it is hoped that some of our experiences in Springfield will in some small way assist other areas in their total program of water pollution control.

Before discussing our approach and relationship with industry, a brief look at the City's background and location and its collection and treatment systems is necessary in order to give a better understanding.

BACKGROUND:

The City of Springfield, Missouri is located in the southwestern section of the State less than 100 miles from the four-corner area of Missouri, Kansas, Oklahoma, and Arkansas. Within this 100 mile radius, the City of Springfield dominates the area as a growth center by providing markets, jobs, product distribution, services, advanced education, and cultural opportunities, among other things. The City and its surrounding area has extensive and varied agricultural operations, diversified manufacturing, mining, and rapidly expanding recreational areas. In its function as a growth center the City has experienced a rather phenomenal increase in population and commercial and industrial activities over the past 20 years. Population has more than doubled to its present 125,000, with most of the industry also having been built during this time. Although there is a wide diversification of manufacturing, the largest single type of wet industry in the City is that of milk and milk product processing. Milk production being one of the largest area agricultural activities. All of the milk produced is funneled into the City either for processing or to transfer points for transporting to other parts of the country. With this and other types of wet industrial processing, wastewater collection and treatment is of paramount importance. In addition to the basic needs for water pollution control, Springfield in its particular location complicates this need even further.

As mentioned previously, recreational activities are increasing at a very rapid rate, particularly those associated with water sports, fishing, and camping. Clear lakes and streams can be found in any direction from the City. The physiography of the area is the reason that these many lakes and streams abound. The City in its location is situated on a plateau and straddles a major drainage divide. This plateau is underlain with a layer of limestone bedrock containing many fractures and solution channels. The wastewater treatment plant receiving streams have their beginnings either in the City or in the immediate vicinity. It is with these conditions in mind that the City of Springfield and most of the surroudning area is keenly aware of the need in most instances for something more than conventional wastewater handling and treatment. It is also the main reason that the joint approach to wastewater treatment is more desirable than individual industrial treatment facilities and their multiple effluent discharge points. Recognizing this, the City in 1955 began a continuing capital improvement program of wastewater facilities and a system of charges to pay for the system's operation, maintenance and debt requirements.

In order to explain the entire program I will briefly discuss the City's collection system and treatment process before relating our joint approach and relationship with industry.

COLLECTION SYSTEM:

Once, while looking at the City archives, we discovered an 1886 ordinance which adopted a separate system of sanitary sewers for use in the City. The ordinance went on to explain that due to the general topography of the City, at that time, storm drainage could be handled by normal surface runoff, thereby making it unnecessary to construct underground storm sewer piping. Since there were no sewers of any type constructed prior to that time, the practice of separate sewer construction has continued until today. However, there are times when we wonder if this is absolutely true when large flows are experienced at the treatment plant due to illegal stormwater connections.

The first sewers were constructed in 1894 and has continued steadily until today. There are now approximately 500 miles of City-owned sewers serving 50 of the City's 62 square miles. A rather major program of trunk sewer construction is now underway to serve not only the remaining area within the City but a large area surrounding it. When this program is completed by 1978, the total service area will be approximately tripled in order to serve both those areas that are currently being developed and those projected by the City's comprehensive metropolitan plan for development.

WASTEWATER TREATMENT PLANTS:

The City is currently served by two wastewater treatment plants which utilize conventional primary treatment followed by the Kraus Modified Activated Sludge Process for secondary treatment. Both plants also employ separate anaerobic sludge digestion. The larger of the two plants, the Southwest Wastewater Treatment Plant, is designed to handle peak flows of 16 MGD with a BOD population equivalent of 310,000. (Figure 1) This plant accepts all of the industrial waste from the City with the exception of one milk bottling plant, which is tributary to the much smaller Northwest Plant.

Presently, the Southwest Plant is nearing both hydraulic and BOD capacity. Plans are now being developed to double the hydraulic capacity and to conform with recently adopted State Effluent Guidelines which call for a maximum effluent BOD of 20 mg/l and NH_3-N (ammonia nitrogen) of 2 mg/l, along with disinfection, turbidity, and taste and odor requirements. BOD removal will be done utilizing the pure oxygen process in an altogether new facility. The existing aeration tanks and air supply system will be used as nitrification tanks to convert ammonia to nitrates to meet the recommended maximum of 2 mg/l NH_3-N. Nitrification will be followed by multi-media filters to remove excess suspended solids. Disinfection is to be done by utilizing ozonation which will also aid in turbidity and taste and odor removal. It is anticipated that these improvements will be under contract in approximately one (1) year.

THE JOINT APPROACH:

The reasons for a joint approach to the solution of water pollution control problems are many and varied and can most certainly be different for different areas. We feel that the more important advantages to the joint approach in Springfield are:

1. Economy of Scales. In other words, it is good sound economics to spread the cost base, both capital and operating, so that everyone in the community benefits directly or indirectly. I feel sure that everyone can understand the soundness of this concept as long as the costs in reality are equitable.
2. Professional Water Pollution Control Plant Operation. Our approach to this has been that the City is in the business of wastewater treatment. While it is quite possible that some individual industries could provide capable operation if they were required to provide treatment; however, the overall results most certainly would be less than that provided at a single well-operated combined plant. Conversely, continued surveillance by City forces would be required if operation is separate, thereby adding costs to the City's operation.
3. Mutual Cooperation and Trust. When the joint treatment method is approached realistically by both the governmental agency and the industry, considerable public good

can result. However, unless all parties work at maintaining this mutual relationship, the whole concept can break down with some very drastic results.

HISTORY:

During April 1955, the citizens of Springfield voted nearly ten (10) million dollars in bond funds for some very major sanitary sewer and treatment improvements. Included in these were replacement of several existing trunk sewers which were in a badly deteriorated condition, construction of several new mains, rehabilitation and enlargement of the smaller treatment plant, construction of the new 12 MGD Southwest Plant, and a new 6 MGD pump station. Of the total $10 million authorized, $4.4 million was issued in the form of revenue bonds and was used exclusively for the treatment plants and pump station. One of the provisions of the election was the establishment of a system of sewer service charges to (1) retire the revenue bond debt, (2) operate and maintain the sewer system, (3) establish a one (1) year's debt reserve ($256,000), and (4) establish a depreciation and replacement fund of $300,000 to be used for unusual or unforeseen experiences that might occur, and (5) to establish a fund to receive any surplus income to use for any minor capital expenditures that might be needed. This charge was established in 1956 and has been, and is, a separate fund used exclusively for the sewer system. Prior to this time the sanitary sewer system was operated by funds from the general revenue of the City.

In establishing the charges Council was attempting to place the system in a self-sustaining financial position and to distribute the charges as equitably as possible.

In enacting the charge ordinance, which prescribed various volume rates to be charged, Council also included the permissive provision for surcharges to be levied against those industries that discharged wastewater with BOD and/or Suspended Solids contents greater than domestic strengths. However, when the sewer service charges first become effective in March 1956 these surcharges were not included.

In December 1959 the new 12 MGD treatment plant was placed into operation with an ultimate design of 12 MGD nominal hydraulic capacity, SS population equivalent of 100,000 and a BOD population equivalent of 165,000. It was immediately seen that hydraulic and SS capacities were in line with predictions of 1955 but the BOD was higher than predicted. However, following several mechanical and operational difficulties which arose during the first six months of operation, these higher loadings of BOD were handled adequately, as the Kraus process for handling shock loads had been incorporated into the design. Treatment then proceeded at about the same level during the following two years.

During the early part of 1962, the City was faced with existing industry expansion, continued construction of residential sewers and accepting the waste from a chemical manufacturing plant whose production had increased twenty fold since 1957. This waste had a soluble BOD PE of 25,000-35,000. In view of this, it was felt that there were three possible solutions to the problem: 1. Increase the treatment plant's capacity much sooner than the ultimate design date; 2. Cut down the strength of waste being received by requiring pre-treatment at certain high strength industries, or; 3. That by enacting the surcharges for above normal strength wastes it would provide a more fair and equitable base for treatment costs and that once enacted, the surcharge would be an incentive for industry to review their operation and possibly cut down on volume and strength of wastes discharged and, if not, the additional revenue would aid in a possible plant expansion.

After review of the situation, in April 1962 City Council passed an ordinance declaring it mandatory to collect surcharges from users that were contributing wastes with a BOD greater than 1.30 pounds per 100 cubic feet (208 mgl) and/or SS in excess of 1.50 pounds per 100 cubic feet (240 mg/l), at the rate of .9¢ per pound BOD and 1.2¢ per pound SS. Following this, letters were sent to all businesses and industries whom it was thought had wastes of these strengths, explaining the reasons for this action and that members of the City Administration would be personally contacting them in the near future to work out individual details.

Considerable sampling, testing, and gauging was done in the initial stages so that a reasonably reliable basis could be used for the surcharge. Also, a great deal of time was spent with both management and technical officials of all industries working out details of the charge, explaining water pollution control terminology, and also assisting where possible in recommending ways that both volume and load could be reduced. It would be presumptious on my part to say that all things went smoothly, as there were numerous facets of the surcharge system that needed deliberation and negotiation. However, I can say that in all instances a spirit of cooperation and mutual trust existed.

The initial results of the program did, indeed, accomplish what was intended in that a certain reduction in BOD and SS loads were experienced and the surcharge produced added revenue. However, faced with steadily increasing population growth and industrial expansion, the City decided to proceed with a minor expansion of the Southwest Plant to increase the BOD handling capability from 165,000 to 310,000 by adding the dual aeration process.

The surcharge program continued at the same rate until May 1971, when the citizens again voted bonds for those major improvements to the sewer system which were outlined in the first part of this paper. To finance these improvements, an increase in the basic volume charge of 35% was enacted immediately; concurrently the surcharge was increased to reflect the actual treatment cost experience averaged over the preceding five (5) years for BOD and Suspended Solids removal, plus the additional 35%. Five (5) years were chosen in order to compensate for rising costs, increasing plant maintenance, and reducing unit costs due to increased quantities of BOD and Suspended Solids. The surcharge finally enacted computed to 1.5¢ per pound of BOD in excess of 1.3 lbs/100 cubic feet (208 mg/l) and 2.5¢ perpound of Suspended Solids in excess of 1.5 lbs/100 cubic feet (240 mg/l).

Again, as in 1962, each industry was contacted before the new charge went into effect to explain the reason for the increase and how it was to take place. In all cases we again experienced only the highest type of cooperation.

The financial system we have followed has been and is one that we feel and hope is as near equitable as we are able to make it. Obviously, time, traditions, politics, and other numerous policy decisions made over the years tend to complicate true equity. However, in attempting to justify our rate structure under the EPA cost recovery requirements, we have explained and feel that it is realistic thusly:

(1) The minimum charge for all users should be adequate to cover all debt requirements somewhere midway through the debt period. This we have maintained. The debt, of course, pays the capital costs for trunk sewers and treatment facilities. Basically these are designed and constructed around volume requirements.

(2) Additional volume charges pay for sewer maintenance, administration, and the treatment of BOD and SS up to domestic strengths. I know many people disagree with the reduced rate theory for higher flow volumes that we have. However, it is our feeling that approximately 90% of all sewer maintenance and administrative matters are spent with residential and commercial problems and not in

industrial areas.

(3) The additional BOD and Suspended Solids charges made on those industries whose load is above domestic strengths is used strictly for excessive treatment costs. This is a straight-forward charge and really the basis for most joint approach methods, although it is only a part of our total financial program.

The basic residential volume charge is $1.35 per month for 500 cubic feet or less. Each additional increment is 34¢ per 100 cubic feet. Additionally, the residential charge is a flat rate based on the average monthly usage for the months of January, February, and March to allow for any summertime lawn and/or garden watering.

The basic minimum commercial and industrial volume charge is $1.44 per month for 500 cubic feet or less. For usages greater than 500 cubic feet the rate structure is lowered in four steps from 34¢ per 100 cubic feet following the minimum down to 10¢ per hundred for all usage over 40,000 cubic feet.

THE RELATIONSHIP WITH INDUSTRY:

Traditionally, over the years cities have provided wastewater handling and treatment services to industries who desired such service, sometimes at a lesser proportional cost than to the individual resident. However, over the past fifteen to twenty years there has been a gradual trend to equalize costs for water pollution control. This obviously has been brought to a culmination in the newly enacted Federal amendments to the Clean Water Act which requires equitable cost recovery. In Springfield we feel that such a system has been in fully successful operation for over ten (10) years as the city-industrial relationship has been excellent. This atmosphere obviously cannot be maintained unless complete cooperation and trust is maintained by both parties at all times. Oftentimes the City has had to meet and reaffirm this position with industrial management personnel which is in most businesses periodically changed due to promotions, transfers, etc. But, summing up all the details of a joint approach, the City has asked no more than for a proportional part of the costs to operate the sanitary sewer system.

NUMBERS AND TYPES OF INDUSTRIES:

Although there are approximately 75 industries in Springfield who are classified under Section D of the Manufacturing Standard Industrial Classification, only nineteen (19) are subject to the industrial waste surcharge. The numbers and types in this category are:

1. Meat Processing	6
2. Milk and Milk Product Processing	5
3. Other Food and Kindred Products	4
4. Commercial Laundries	3
5. Pharmaceutical	1

Of the total dollar volume the milk industry pays more than 55% of the surcharge receipts.

The total load that these nineteen (19) industries place on the system and the treatment plants is:

1. Flow - 8%

2. BOD - 48%

3. Suspended Solids - 18%

If one takes each of these equally, the average is 25%. Also, if one looks at the total system income from sewer service charges, you will see that these nineteen (19) industries pay 25% of the total.

Sampling and Analyses:

At the very outset of the program in 1962 a sampling crew started a continuous collection of hourly samples from all industries for a three month period to obtain enough background data as was possible in order to arrive at a good average. In order to get a reasonably good composite, four different methods have been used.

1. Water Meter Reading Each Hour--
   This is the most frequent use, especially at the smaller industries. The total usage each hour is computed and the sample composited accordingly. Some doubts were raised intially about this method; however, over the past ten (10) years the highs and lows have tended to smooth out to a reasonable rate.
2. Kennison Nozzle with Rate Indicator and Totalizer--
   Three of the largest industries (two of them milk processors) installed these to measure exactly what is discharged to the sewer. Not

only are these meters used for monthly billing purposes, but also for sampling and compositing. The two milk processors also installed automatic samplers of the Trebler type whereby the sample is collected continuously and proportionally and then pumped to a refrigerator for storage. Once each month our sampling crew goes to these plants and starts the sampling equipment. Checks are made during the day to see that it is operating correctly and at the end of the 24-hour period the sample is removed from the refrigerator, half is left with the industry and the other half taken to the wastewater treatment plant laboratory. Parallel tests are run in the industries' laboratories for comparison. Occasionally there are some differences, but they have always been resolved. The industry with the other Kennison Nozzle is also sampled monthly by taking hourly composite samples.

3. Parshall Flume with Rate Indicator and Totalizer---One large milk product processing plant installed a parshall flume to also measure directly what is discharged to the sewer. Compositing is done as with the Kennison Nozzle.

4. Manning's Formula---

One large slaughter and packing house gets their process water from a well which is not metered. Their waste is also discharged unmetered through two separate sewer lines. In order to compute volume and to composite samples, the quantities are measured by taking the depth and recording the velocity. This data is then taken to the laboratory where the chemist uses Manning's discharge curve to composite.

All testing is done in the wastewater treatment plant laboratory in accordance with the latest edition of "Standard Methods". Multiple dilutions are set up in order to get good BOD range coverage. Following analysis, the test results, along with the composite data sheets, are forwarded to the administrative offices where the surcharge is computed and billing instructions are written.

Sampling and testing frequency was altered many ways over the first few years. Finally it was determined that the four (4) largest firms would be tested each month, the next six (6) were tested every other month, and all industries sampled quarterly. The basis for this frequency was the amount of revenue each produced.

Waste Compatibility and Pretreatment:

In a joint municipal-industrial system the possibilities of having a waste that is amenable to biological, physical, and chemical treatment is quite good in comparison to individual industrial wastes. However, there are certain industrial wastes that require pretreatment. In Springfield's case practically all of the industry is of the food processing category whose wastes are readily treatable, although shock loads from these industries can be disasterous to a wastewater treatment plant. In combating this we have had numerous conferences with industrial management personnel to explain the consequences of "shock loads" on the treatment facilities and that should an accidental spill occur, to alert treatment plant personnel immediately. Conversely, several industries have taken steps to eliminate the possibilities of spills and to also reduce BOD and SS loads by taking physical in-plant measures and by having periodic supervisory meetings to urge operational cooperation. To this end we are most grateful.

Two (2) large industries have wastes that require pretreatment prior to discharge into the sanitary sewer. One is a pharmaceutical manufacturing waste and the other is a metal plating waste. The pharmaceutical plant employs a large holding basin to obtain a uniform waste mixture and also allow volatile phenolic and other similar compounds to evaporate. Following the holding basin the waste is neutralized with caustic soda to pH 7 and aerated for 24 hours. This process removes volatile compounds, neutralizes and removes approximately 50% of the BOD and COD prior to being discharged to the city system. The second industry has a metal plating waste from the manufacture of small electric motors. The waste contains significant quantities of zinc and hexavalent chromium. The metals are removed by a very elaborate facility constructed in-plant. The chromium is reduced to the trivalent state by sodium bisulfite reduction, it is then removed along with the zinc by caustic soda precipitation. The waste stream contains less than 1 mg/l of both zinc and chromium. The metal sludge is then removed by a metal reclaiming company.

SUMMARY:

The joint treatment approach to wastewater treatment is a reasonable method to a water pollution control program in a great many areas of the country if it is accomplished in the true sense, particularly in this day of environmental awareness.

While it is not perfect in many respects, the program we have in the City of Springfield works very well by producing sufficient revenue on as nearly an equitable basis as we are able to realistically operate. Taking all aspects into consideration, the cost sharing so that everyone in the community benefits, is the primary reason for joint treatment. Other benefits resulting from this are better treatment, consequently less pollutional materials discharged to the receiving streams, and a closer relationship between government and industry.

CITY OF SPRINGFIELD, MISSOURI WASTEWATER TREATMENT PROCESS
(KRAUS)

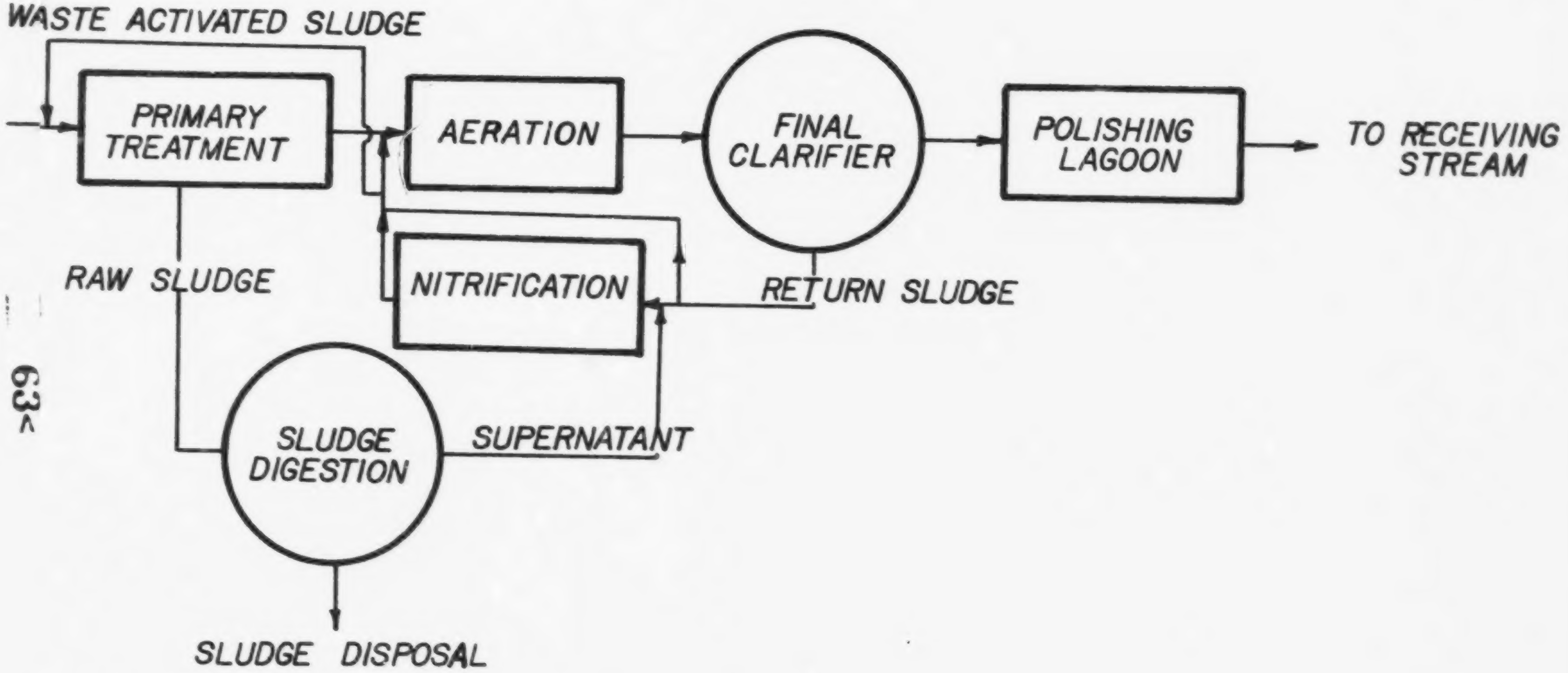

WASTE ACTIVATED SLUDGE
PRIMARY TREATMENT
AERATION
FINAL CLARIFIER
POLISHING LAGOON
TO RECEIVING STREAM
RAW SLUDGE
NITRIFICATION
RETURN SLUDGE
SLUDGE DIGESTION
SUPERNATANT
SLUDGE DISPOSAL

FIGURE I

CITY OF SPRINGFIELD, MISSOURI
WASTEWATER TREATMENT PROCESS
CURRENTLY IN DESIGN FOR S.W. PLANT

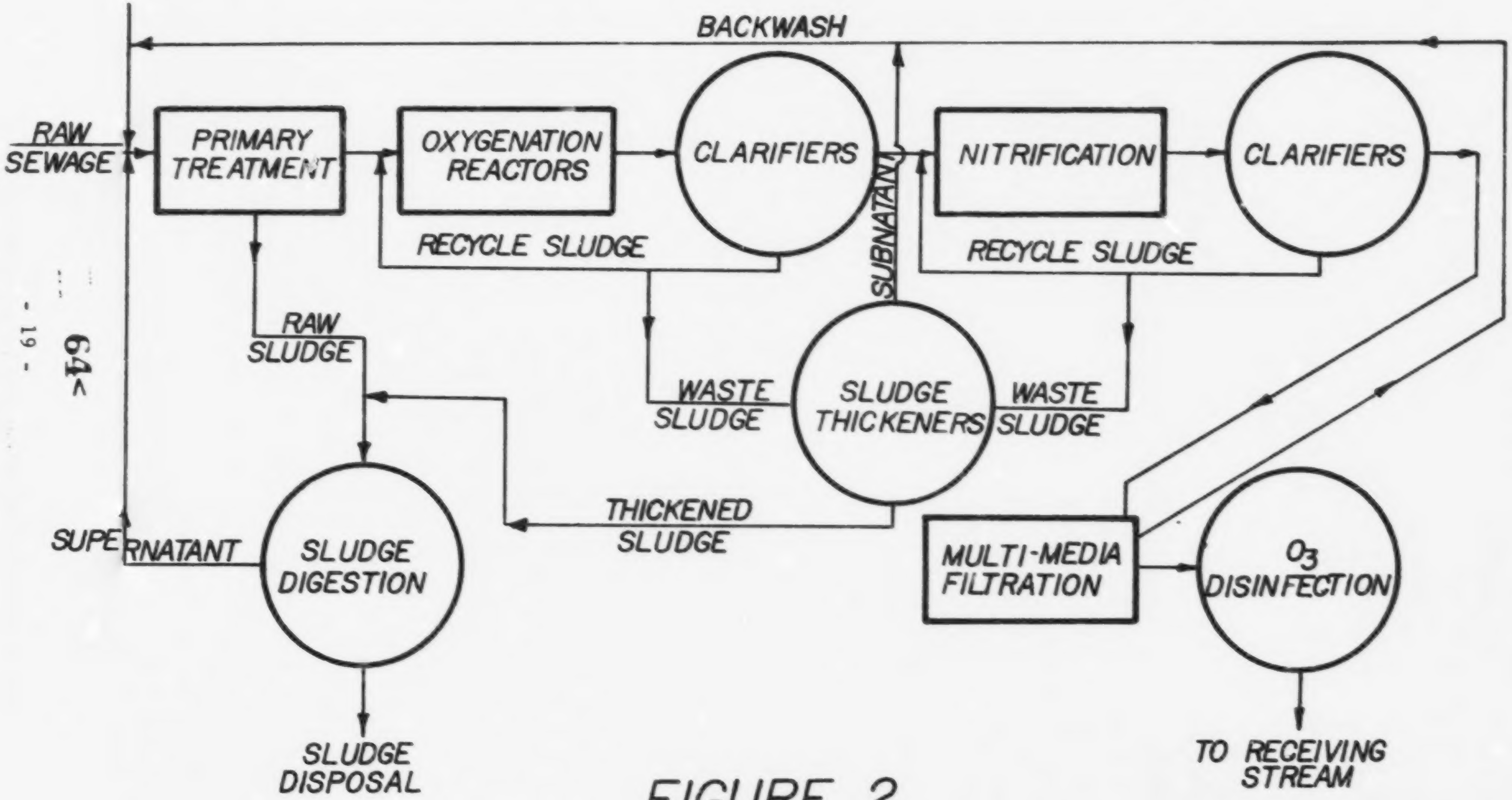

BACKWASH
RAW SEWAGE
PRIMARY TREATMENT
OXYGENATION REACTORS
CLARIFIERS
NITRIFICATION
CLARIFIERS
RECYCLE SLUDGE
SUBNATANT
RECYCLE SLUDGE
RAW SLUDGE
WASTE SLUDGE
SLUDGE THICKENERS
WASTE SLUDGE
THICKENED SLUDGE
SUPERNATANT
SLUDGE DIGESTION
MULTI-MEDIA FILTRATION
O_3 DISINFECTION
SLUDGE DISPOSAL
TO RECEIVING STREAM

FIGURE 2

How Dean Foods Handles The Waste Problem at the Chemung, Illinois Dairy Plant

George Muck and Ken Killam

The Dean plant at Chemung is a fluid milk plant processing about 1.1 million pounds of milk per day. This plant processes and bottles a complete line of fresh dairy products including soft serve ice milk mixes. Cultured products, sour cream, buttermilk, and yogurt, are also manufactured at this location. Cottage cheese was produced at this plant until April, 1972.

Waste control and waste water treatment have been a part of this plant operation since 1950. This has been necessary because Chemung is a very small community of only a few homes and does not have a municipal waste disposal plant. Throughout the years improvements for waste reduction and segregation have been made both in the plant and in the treatment system. The following examples are some of the practices used to recover and segregate waste inside the plant:

1) Fresh pasteurized product losses are recovered for use in ice cream mix.

2) Product losses which cannot be reused are segregated for animal feed.

3) Whey from cottage cheese manufacture was recovered.

4) Cottage cheese rinse water was disposed of through sprinkler irrigation.

5) Uncontaminated water is segregated for cooling

tower treatment and the discharge by-passes the treatment plant.

The unsegregated waste is discharged to the waste treatment plant and consists of approximately 80,000 gpd and 1150 pounds of BOD_5 per day. Waste water coefficients for the unsegregated waste load are approximately 0.6 pounds waste water per pound of milk and 1.0 pound BOD_5 per 1000 pounds of milk. Table 1 shows the monthly averages for these characteristics during 1971 and 1972. The daily averages and the daily maximum and minimums are also given in this table.

The waste treatment facility consists of an activated sludge system followed by two lagoons. A flow scheme for this system is given in Figure 1. The influent enters an aerated waste holding tank (A) where the flow and BOD_5 is partially equalized. Nitrogen is also added to the influent at this point. The waste then goes into two activated sludge aeration tanks (B) which are operated in series. The retention time in these tanks is approximately 24 hours and a BOD_5 reduction of about 75% is obtained. The next step is two gravity clarifiers (C) which operate in parallel with approximately 80,000 gpd effluent overflow and 160,000 gpd return sludge underflow. Activated sludge effluent receives additional treatment in two aerated lagoons (D) operated in series with 20 days retention time to obtain an additional BOD_5

DAIRY PROCESS WASTE WATER CHARACTERISTICS

Table 1.

DEAN FOODS COMPANY CHEMUNG, ILLINOIS

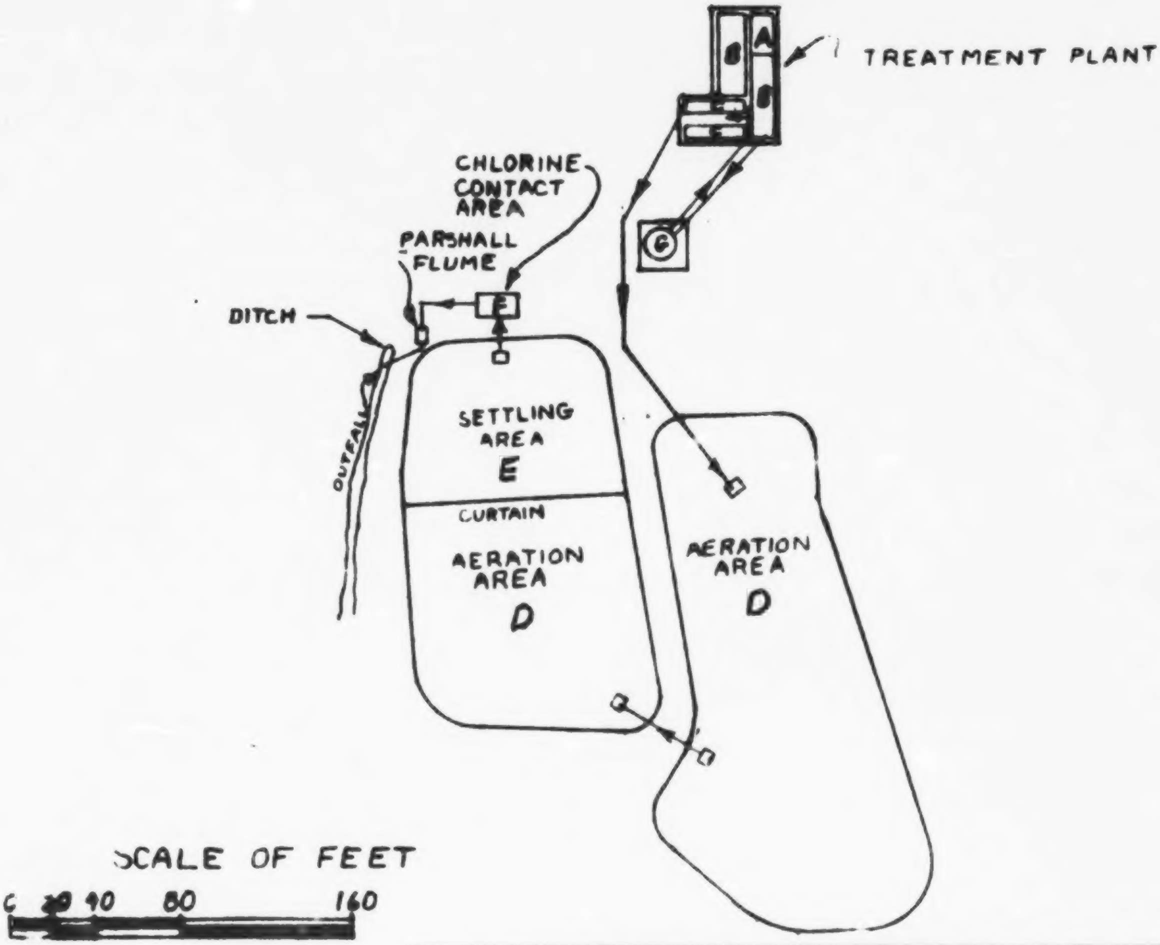
MONTH	FLOW gpd	BOD$_5$ mg/l	BOD$_5$ POUNDS PER DAY	pH	# WASTE WATER PER # MILK	# BOD$_5$ PER 1000 # MILK
1-71	88,000	1494	1096	7.49	0.56	0.83
2-71	93,000	2041	1583	7.87	0.55	1.13
3-71	83,000	2070	1433	7.79	0.51	1.06
4-71	91,000	1575	1195	7.02	0.59	0.93
5-71	92,000	1476	1132	7.72	0.62	0.91
6-71	98,000	2117	1730	6.87	0.75	1.58
7-71	89,000	1900	1410	6.80	0.63	1.23
8-71	98,000	1818	1486	6.60	0.72	1.30
9-71	101,000	1135	956	6.65	0.73	0.80
10-71	104,000	1609	1396	7.67	0.73	1.25
11-71	80,000	1215	811	7.90	0.57	0.69
12-71	80,000	2470	1648	7.40	0.55	1.36
1-72	64,000	1520	811	7.14	0.43	0.66
2-72	63,000	1638	860	6.52	0.49	0.80
3-72	61,000	1450	738	6.32	0.42	0.59
4-72	63,000	1430	751	7.14	0.48	0.68
5-72	63,000	1368	719	6.85	0.51	0.69
6-72	69,000	1618	930	7.00	0.59	0.95
7-72	81,000	1854	1252	6.82	0.59	1.25
8-72	90,000	2242	1683	7.30	0.68	1.53
9-72	82,000	1570	1074	6.75	0.62	0.97
10-72	70,000	1207	705	7.10	0.50	0.61
11-72	76,000	1604	1017	8.24	0.53	0.91
12-72	75,000	1962	1227	7.33	0.55	1.18
Daily Avg.	81,400	1712	1156	7.16	0.58	0.98
Daily Max.	140,000	3400	2667	9.10	0.75	1.58
Daily Min.	23,000	817	670	5.60	0.42	0.61

Estimated SS = 300 mg/l or 200 pounds per day

A. Raw waste equalization tank
B. Activated sludge aeration tanks
C. Clarifiers
D. Aerated lagoons
E. Settling lagoon
F. Chlorinator
G. Sludge aerobic digester

Figure 1

WASTE TREATMENT FLOW SCHEME


B
A
C
TREATMENT PLANT
G
CHLORINE CONTACT AREA
PARSHALL FLUME
F
DITCH
OUTFALL
SETTLING AREA
E
CURTAIN
AERATION AREA
D
AERATION AREA
D
SCALE OF FEET
0 20 40 80 160

Outfall & Discharge

Flume and Ditch to Piscasaw Creek

at Village of Chemung

County of McHenry, State of Illinois

Application by Dean Foods Company
25 June 1971 Date
SHEET 2 of 3

reduction of about 70%. The total BOD_5 reduction is 90-95%. A lagoon settling zone (E) of 4 days retention time achieves a ss reduction of approximately 85%. The lagoon effluent is chlorinated (F) and mixed with the segragated cooling water prior to discharge to the stream. An aerobic sludge digester (G) is used to further reduce BOD_5 and concentrate ss in waste activated sludge. The digested sludge is applied to an approved 21 acre irrigation site.

The effluent characteristics from the various steps in the operation are shown in Table 2. These figures are monthly averages for 1971 and 1972 and again the daily averages and maximum and minimums are given. The final effluent consists of approximately 80,000 gpd chlorinated lagoon effluent and 200,000 gpd cooling water discharge. The combined effluent contains approximately 30-60 mg/l BOD_5, 35 mg/l SS, 25 mg/l PO_4, 5 mg/l NH_3 and 0.5 mg/l NO_3. The effluent characteristics given in Table 2 are displayed graphically in Figures 2 and 3. Figure 2 shows the suspended solids variation monthly for the activated sludge effluent and the lagoon effluent. Figure 3 shows the monthly variation in BOD_5 for the influent, activated sludge effluent, and the lagoon effluent.

The major components of the waste treatment complex were initially installed as follows:

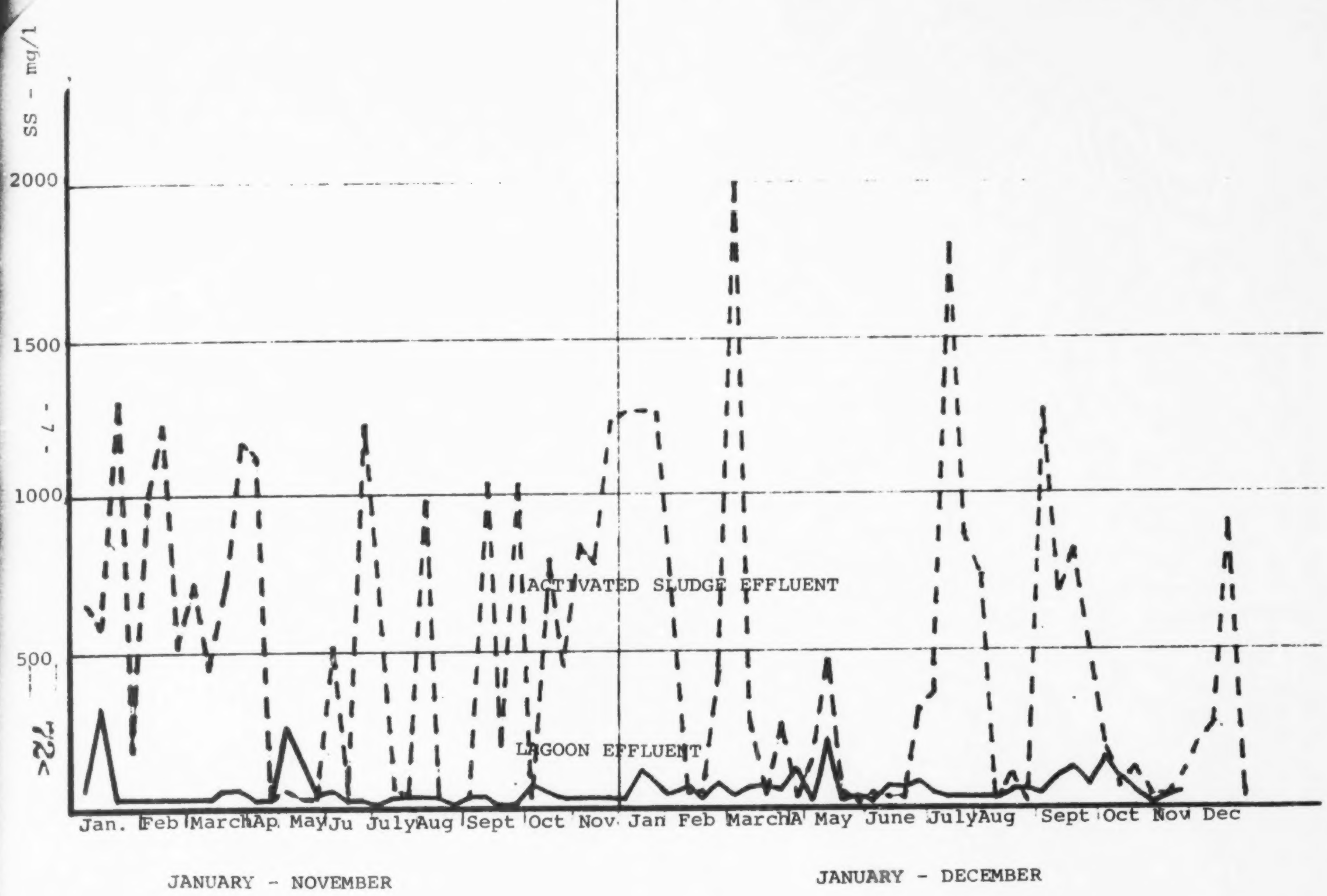
Table 2.

EFFLUENT CHARACTERISTICS

DEAN FOODS COMPANY - CHEMUNG, ILLINOIS

MONTH	ACT. SLUDGE EFF.		LAGOON EFF.		FINAL EFF.		
	BOD_5 mg/l	SS mg/l	BOD_5 mg/l	SS mg/l	BOD_5 mg/l	SS mg/l	DO mg/l
1-71	964	680	258	111	77	14	7.1
2-71	1001	910	247	30	148	79	
3-71	602	764	201	45	98	29	7.3
4-71	815	585	180	30	64	43	5.1
5-71	160	40	795	634	114	83	7.1
6-71	365	595	120	40	56	35	7.3
7-71	136	268	58	25	44	14	8.1
8-71	115	342	65	25	26	15	7.5
9-71	581	578	68	21	22	14	7.0
10-71	926	499	70	30	32	55	7.7
11-71	883	953	65	30	19	26	8.1
12-71	581		84		44	12	6.6
1-72	875	1246	135	78	49	6	8.0
2-72	540	303	129	49	103	36	12.7
3-72	744	648	109	63	15	26	7.2
4-72	46	31	36	123	35	28	7.4
5-72	129	170	137	78	23	28	8.0
6-72	114	102	100	65	33	44	9.1
7-72	825	788	84	36	8	25	6.3
8-72	325	221	104	48	45	22	8.1
9-72	165	848	80	86	11	56	7.6
10-72	82	107	69	81	6	55	6.9
11-72	132	298	51	42	35	59	7.9
12-72	172	349			23	40	7.8
Daily Ave.	470	492	139	80	47	35	7.6
Daily Max.	2100	1300	2200	1200	260	303	16.4
Daily Min.	20	30	40	10	1	4	3.5

Figure 2.
DEAN FOODS COMPANY
CHEMUNG, ILLINOIS



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1) 1950 - One aeration tank and one clarifier.
2) 1961 - Second aeration tank and clarifier.
3) 1967 - Sludge digester and irrigation site.
4) 1968 - Lagoons and chlorinator.

The replacement cost of these components is estimated at over $500,000. Annual operating cost is estimated at $50,000 including personnel.

Since January 1972 a technically educated operator has been employed to conduct waste sampling and analyses, interpret results, and operate the treatment plant in a scientific manner. Prior to that time the responsibility was divided between the quality control laboratory and maintenance department.

The final effluent has had little impact on the receiving stream as shown by the upstream and downstream data in Table 3. The final effluent of approximately 280,000 gpd is discharged to a stream with a ten year low flow of around 890,000 gpd. Upstream and downstream BOD_5 and DO have been nearly identical.

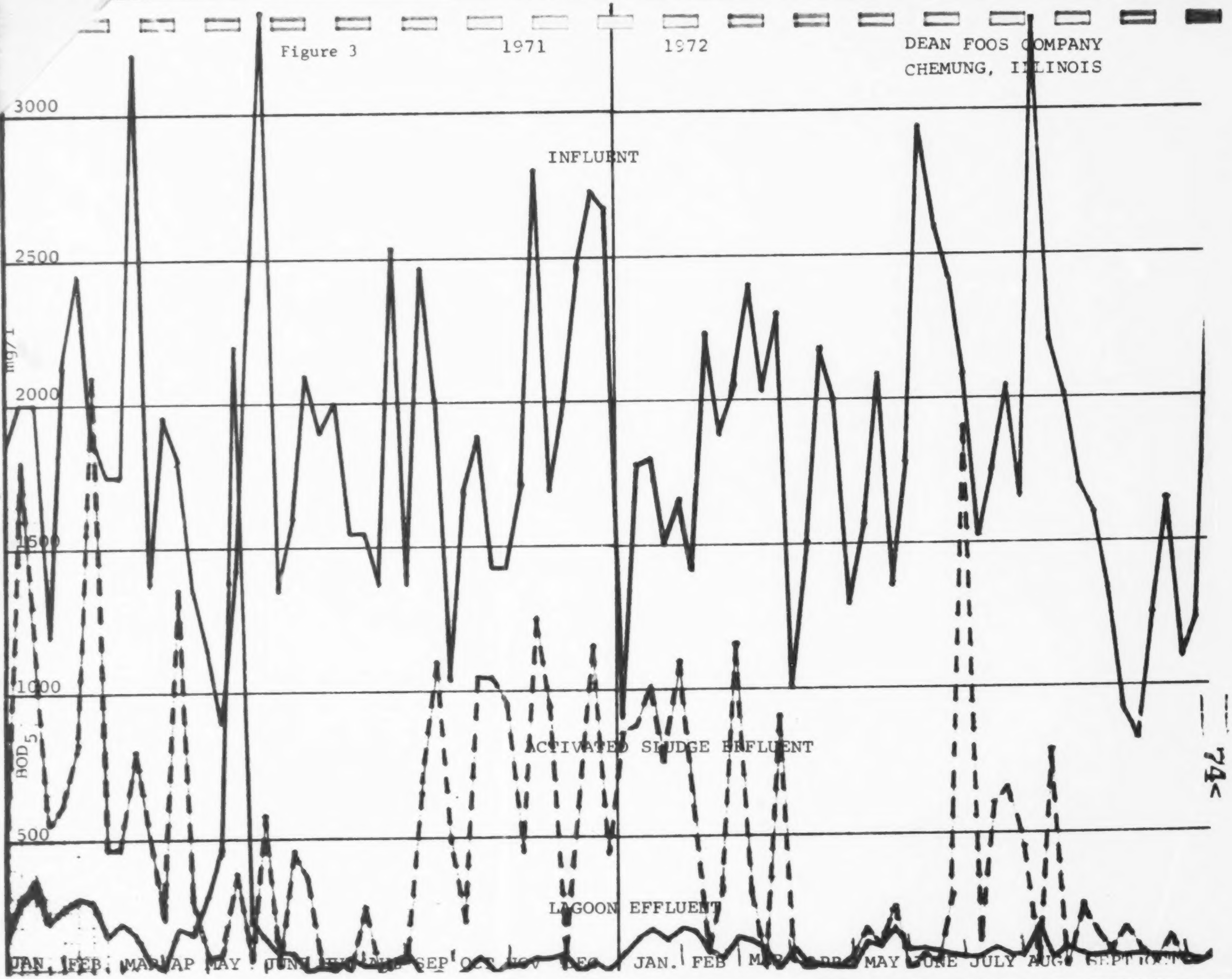DEAN FOOS COMPANY
CHEMUNG, ILLINOIS
1971
1972
INFLUENT
ACTIVATED SLUDGE EFFLUENT
LAGOON EFFLUENT
BOD5 mg/l
3000
2500
2000
1500
1000
500
JAN. FEB. MAR. AP MAY JUNE JULY AUG SEP OCT NOV DEC. JAN. FEB MAR. APR. MAY JUNE JULY AUG. SEPT OCT
74<

Figure 3

Table 3.

WATER QUALITY - RECEIVING STREAM

DEAN FOODS COMPANY - CHEMUNG, ILLINOIS

MONTH	UPSTREAM		DOWNSTREAM	
	BOD_5 mg/l	DO mg/l	BOD_5 mg/l	DO mg/l
1-72	5	13.6	5	13.5
2-72	10	14.4	11	14.5
3-72	14	10.9	12	10.2
4-72	8	12.2	6	12.2
5-72	4	14.6	2	14.7
6-72	4	10.1	5	11.9
7-72	9	11.2	11	11.7
8-72	3	11.3	3	12.5
9-72	3	11.0	6	11.3
10-72	3	12.0	3	12.1
11-72	3	13.5	1	14.0
12-72	1	14.1	0	14.3
Avg.	6	12.4	5	12.7
Daily Max.	30	16.0	30	16.6
Daily Min.	0	8.0	0	9.6

ALTERNATE METHODS OF TREATING OR PRETREATING DAIRY PLANT WASTES

by

William C. Boyle and L. B. Polkowski
Polkowski, Boyle & Associates
Madison, Wisconsin

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IV

Dairy Waste Compatibility in Municipal Systems

Wastewater Characteristics - In comparing dairy wastewaters with domestic sewage it is apparent from Table I that there are some significant differences that have a bearing on the treatability and the influence of dairy wastewater on municipal treatment systems. It is apparent that dairy wastewater is a strong waste in terms of most parameters reported when compared to domestic wastes. The BOD values are high and vary widely, but the fact that the BOD values are high is also indicative that the wastewater is amenable to biological treatment. Because the values of BOD for dairy wastes are considerably higher than that of typical strong domestic wastes, often surcharge rate structures are applied when discharged to municipal systems. The suspended solids or filterable solids are higher than domestic wastewater, but the solids in dairy wastewater are too finely divided to permit separation by gravity settling whereas for domestic wastewater there is a high fraction of suspended solids that are settleable and, thus, amenable to primary sedimentation treatment. Primary sedimentation practices usually provide good removals at low operating and capital costs relative to the biological treatment costs associated with secondary treatment. It is apparent in Table I that the average Phosphorus and Grease content of dairy wastes are higher than normally expected in domestic wastewater. Removal costs in municipal treatment related to P removal may be assessed to the contributing source thereby increasing overall treatment costs for use of municipal systems. The range of grease concentrations encountered in dairy wastes may exceed acceptable limits imposed by ordinances.

TABLE I

Comparative Wastewater Characteristics

Wastewater Characteristic	Dairy Wastewaters				Domestic Sewage (9)		
	Harper (6)		Numerow(10)	Other			
	Range	Ave.			Strong	Medium	Weak
BOD, 5 day 20°C	450 - 4790	1885	1890	*15-4790	300	200	100
Solids, total	135 - 8500	2397	4516		1200	700	350
Dissolved, Total	---	---	3956		850	500	250
Fixed	---	---	---		525	300	145
Volatile	---	---	---		325	200	105
Suspended, Total	*24 - 5700	---	560		350	200	100
Fixed	---	---	---		75	50	30
Volatile	*17 - 5260	---	---		20	10	5
Settleable Solids ml/liter	---	---	---	0.3-5.0(11)	20	10	5
Nitrogen, Total as N	15 - 180	76	---		85	40	20
Organic	---	---	73.2		35	15	8
Ammonia	---	---	6.0		50	25	12
NO_2	---	---	---		0	0	0
NO_3	---	---	---		0	0	0
Phosphorus (Total as P)	11 - 160	50	59		20	10	6
Grease (fat)	35 - 500	209	---		150	100	50
pH	*5.3 - 9.4	7.1	---		---	---	---

Note: *Industry values (6)

Fats, Oils, and Greases (FOG) - In municipal treatment systems treating domestic and industrial wastes, ordinances are usually adopted to protect treatment works by restricting the concentration of FOG to less than 100 mg/l. Discharges to the collection system in excess of 100 mg/l would be prohibited or require pretreatment. This particular requirement has been adopted widely for municipal treatment systems largely due to the available "Model Ordinances" which serve as a guideline for drafting ordinances applicable to specific municipal systems.

The principal difficulty experienced with this criteria is that the analytical methods employed do not account for the wide variety of substances included in the determination; i.e., any material which is hexane soluble and would be subsequently evaporated with the hexane at 100°C, and nor does it distinguish between that matter which is of mineral origin (non polar) versus the fatty matter which may be of animal or vegetable origin (polar). What appears to further complicate the collective nature of the analytical method is that there is no differentiation of the organic matter as to its physical state; i.e., whether these materials are present in wastewater as a liquid or a solid, which may readily separate by floatation, or whether they may be present in finely divided states, emulsified or soluble and not be readily separable. Also, no distinction is made as to the ability of the wastewater treatment facilities to remove these substances with the usual type of treatment afforded.

For example, although most municipal treatment plants have devices in primary and now, secondary settling units to remove floatable substances by retention baffles extended below the water surface with scum movement and withdrawal provisions, very limited attention has been drawn to the fact that fats, oils, and greases of animal and vegetable origin are treatable biologically in both aerobic and anaerobic treatment units whereas FOG of mineral origin are considered to be non-biodegradable. However, in order for biological degradation to occur, the FOG of animal and vegetable origin must be in physical states which will permit the biological mass to be in contact with the material to be oxidized. Thus, if the material separates, or floats on the surface of treatment units, the opportunity for biological degradation is greatly reduced and this phenomenon has long attributed to the desired exclusion of these substances from municipal treatment systems. It is well known that anaerobic treatment systems such as anaerobic digesters are particularly adaptable to the degradation of FOG from animal and vegetable origin, and are capable of higher degrees of volatile solids reduction and greater volumes of methane gas production per pound of volatile solids reduced than for other organic matter common to municipal wastewater systems. This is not so for FOG of mineral origin wherein these substances effectively coat insoluble surfaces and in high concentrations will effectively impair biological treatment by interfering with the normal mass transfer functions of the biological system.

In instances where gross oil or greases are present in wastewater regardless of the origin whether mineral or from animal and vegetable sources, these substances which are readily separated by traps or limited gravity separation units, should not be discharged to a municipal collection system where adverse effects of sewer clogging, excess accumulations in wet walls, or

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overloading of scum removal equipment occurs.

For the discharge of dairy wastes to a municipal system, in that the FOG are biodegradable, the principal concern should be directed to whether or not the greases present will readily separate, cause sewer clogging, or excessive accumulations. Floatable greases should be removed if these adverse affects are noted; however, FOG in highly dispersed states, although in concentrations that may exceed the presently accepted level of 100 mg/l should not be excluded from municipal treatment systems. For example, it would not be very practical to require biological pretreatment of dairy wastes for the purposes of removing FOG of a dispersed nature if the municipal system is going to utilize similar biological treatment processes. It is expected that there will be a concentration limitation imposed on FOG of mineral origin and FOG of all types which are readily floatable. Likely no restrictions would be placed on FOG in dispersed states of animal and vegetable origin.

Municipal System Discharge - As indicated by others, the practice of discharging dairy wastewaters to municipal systems is commonplace. In that dairy wastes are highly amenable to treatment generally, the main concerns have been directed to the intermittant nature of the waste discharges wherein the treatment plant may be heavily loaded or subject to large variations for certain wastewater characteristics which may adversely affect treatment. Because of the emphasis on establishing rate structures which reflect the costs to the users of the system for appropriate Federal construction grant monies, the dairy industry as with other wet industries are becoming more waste conscious, employing in-plant waste saving devices and overall in-plant improvements to minimize waste discharges. The characteristics of dairy waste discharges which have received some attention, the degree of which is somewhat related to the percentage of dairy waste to total municipal waste sources wherein a high proportion of dairy wastes to total municipal wastes appears to highlight the following waste characteristics:

1. The highly variable nature of dairy wastewater strength in terms of BOD which may necessitate the employment of pretreatment in the form of aerated holding facilities. The ability of a municipal wastewater system to treat highly variable wastewater strengths depends upon the dilution and attenuation of the characteristic with wastes from other sources and of more concern is the resident times or detention times in the treatment units. A wastewater treatment plant that employs extended aeration having detention periods approaching 24 hours, little to no benefit can be realized in employing equalization or holding facilities prior to discharge to the municipal system. In other instances, where treatment detention periods are shorter, recirculation may assist but the overall effects must be observed and analyzed on a case by case basis.

2. Another dairy wastewater characteristic which draws considerable attention is related to the pH variation of the wastewater particularly when peak alkaline conditions occur during cleanup operations. In that an upper limit of pH 9.5 has been adopted in certain Sewer Ordinances for the discharge of wastes to a municipal system, this value can be easily exceeded during periods of washing. Equalizing the waste discharge to attenuate the pH variation may be recommended but not always be warranted.

Whereas pH values below 5.5 may be harmful to sewers because of the corrosive nature of the wastewater, generally sewer construction of alkaline earth materials would not be so effected by high pH discharges. In terms of biological waste treatment, large variations in pH over a short period of time in the biological treatment unit would be undesirable. The variation of pH at the source or industry discharge may have little bearing on the pH in the biological treatment unit and, therefore, should be monitored in the treatment unit, not the discharge to the unit, to determine the pH range encountered. Again, in activated sludge treatment systems with long detention periods, the pH variations are usually slight although large variations in pH may be evident in the incoming waste stream. Regulation of discharges to a municipal waste system and required pretreatment must be consistent with the desired end result sought.

3. With the increased emphasis on removing nutrients such as Nitrogen and Phosphorus from wastewaters that contribute to eutrophication or fertilization of lakes and streams, this may place an additional burden on contributors to the system particularly from point sources where the use of phosphorus bearing cleaning compounds are employed. Costs for treatment in some instances have been prorated on a per pound basis of P present in the waste discharges to the system. The methods employed for P removal usually result in high operating costs due to chemical additions required for P removal and the handling of the resulting sludge with fairly nominal annual costs associated with capital improvements related to this removal function.

Selection Objectives

In the selection of a wastewater treatment alternative, a number of factors must be evaluated prior to making a final choice. Among those objectives which most often dictate process selection are (a) effluent criteria, (b) site limitations, (c) wastewater characteristics, (d) wastewater variation, (e) expected life, and (f) cost to treat. A brief outline of these objectives will precede a more extensive discussion of specific treatment alternatives.

a. Effluent criteria - The requirements for effluent quality from the dairy industry have been most recently released by U.S. EPA in August, 1972, based upon two comprehensive studies of the dairy industry: (1) "Study of Wastes and Effluent Requirements of the Dairy Industry" by A.T. Kearney & Co. (8), and (2) "Dairy Food Plant Wastes Treatment Practices" by Ohio State University (11). Currently,these requirements based on "best practicable control technology currently available" cover only the wastewater parameters of BOD and suspended solids. For new plants under construction or existing plants now beginning abatement programs, effluent BOD and suspended solids concentrations of 30 mg/l are expected regardless of influent characteristics unless there are unusual or restrictive characteristics.

Public Law 92-500, the Federal Water Pollution Control Act Amendments of 1972, further states that even a higher level of treatment will be required by July 1, 1977, in those areas where secondary treatment will not meet water quality standards. Water quality standards must be achieved in all instances and every evidence indicates that these standards will be whole body contact recreation plus fish and aquatic life standards. It is likely, therefore, that requirements for the dairy industry will become more stringent in years to come. Furthermore, additional water quality parameters such as phosphorus and nitrogen will undoubtedly be added to the list.

Restrictions on phosphorus removal have already become a reality in many parts of the country. In Wisconsin industrial discharges in excess of 8,750 pounds of total phosphorus per year must achieve 85% removal if discharged to the Lake Michigan watershed. It is apparent, then, that the dairy industry will have to be concerned about its phosphorus discharges in the near future.

In process selection, therefore, it is important to consider flexibility and versatility of the flowsheet in providing reliable and consistent effluent quality. One must consider design based upon both expansion of production and increased restriction of pollutant discharge.

b. Site limitation - In the selection of either pretreatment or complete treatment facilities, the constraints of the site often play a controlling role. Low first cost processes normally require substantial land areas and may restrict development within one quarter to one-half mile of the facility. Urban locations may be restricted by odor, noise, or esthetic regulation. Costs to pump or otherwise transport wastewaters to remote locations should not be overlooked.

c. Wastewater characteristics - Wastewaters from dairy plant processes normally include substantial concentrations of fats, milk proteins, lactose, some lactic acid, minerals, detergents, and sanitizers. Normally, a major fraction of the pollutants is in a dissolved organic and inorganic form not susceptible to plain sedimentation or floatation. The strength and quality of wastewater varies widely even within plants producing the same dairy food products. That plant management plays an important role in these characteristics is brought out by the Ohio State Report (11). A complete compilation of wastewater characteristics is presented in this document.

The wastewaters from most dairy food operations are substantially higher than domestic wastewaters as measured by BOD, COD, total organic carbon and volatile solids. The carbon to nitrogen ratio of dairy food processing wastewaters is normally higher than that of domestic waste as is the carbon to phosphorus ratio. Thus, processes ordinarily acceptable for handling domestic wastewaters may require considerable modification for handling dairy process wastewaters. Furthermore, combined treatment of dairy plant wastes with municipal wastes may be substantially influenced by the proportion of dairy plant to municipal waste flows.

d. Wastewater variation - Discharges of dairy wastewater are often batch or slug dumps producing wide variation in flow and quality. Treatment processes may be sensitive to either qualitative or quantitative shock loads caused by these variations. It is important to evaluate treatment performance reliability in light of these expected variations.

Equalization, neutralization, or other forms of load equalization must be considered in concert with the treatment processes which are sensitive to widespread variation.

e. Expected life - The treatment facility being designed by industry normally has a short design period owing to the uncertainty in production forecasts. Currently, this policy would seem to be of considerable advantage, especially to the small dairy operation. Yet, as mentioned earlier, every consideration should be given to building in flexibility and versatility even for short-term programs. Considerable advantage may accrue to dairies considering modular construction to meet current needs with an eye to the future.

f. Cost to treat - Of greatest impact in process selection is the cost to treat which includes both capital investment and operational maintenance costs. All too often, process selection based on first cost has proved to be the poorest choice owing to excessively high operation and maintenance costs. Considerable care must be observed in interpreting cost data in the literature. Hidden costs such as sludge handling and whey separation and treatment are often neglected in these analyses. Data on municipal treatment process costs are of little value in assessing costs to treat dairy wastewaters.

Treatment Alternatives

In the discussion of alternatives to dairy wastewater treatment, no reference will be made to whey treatment or handling. The processing of whey is extremely important in the overall waste disposal program and should be considered separately from other wastewater disposal problems. In the overwhelming majority of cases whey should not be treated in combination with other dairy wastewaters. The characteristics of whey normally lead to serious treatment plant upsets and would result in excessively high costs to treat by most procedures currently employed.

Biological Waste Treatment

Dairy plant wastewaters are most often treated by biological treatment processes owing to the relatively high fraction of readily biodegradable compounds present. Since the major fraction of pollutants in dairy wastewaters is dissolved and colloidal organic and inorganic matter, chemical coagulation and precipitation of milk waste constituents has met with only partial success resulting in relatively poor removal of organic matter and producing voluminous quantities of chemical sludges. Biological processes, then, provide the most economical process for removal of the substances. The rate of biochemical stabilization of the organic compounds in dairy food wastewaters is normally dictated by the rate of degradation of milk proteins. Limitations of essential growth nutrients such as nitrogen or phosphorus, the toxic effect of detergents or sanitizers, or inhibition or repression of the activity of specific enzymes caused by lactic acid or whey proteins may further exert a controlling influence on stabilization rates. In general, however, a biological process can be designed that will effectively and consistently stabilize a major fraction of the degradable waste constituents. This may be most effectively accomplished by an assortment of processes including aerobic systems, anaerobic systems, or combinations of the two processes in either suspended or fixed film reactors.

The design of biological wastewater treatment processes is dependent upon (a) the stoichiometry of the biochemical reaction, (b) the rate at which this reaction proceeds, and (c) the dispersion of the waste constituents within the reaction vessel. A vast literature exists in sanitary engineering related to the modeling of biological treatment processes. Investigators recognize the great complexity of the system and considerable effort has been recently exerted to develop a unified concept acceptable to the profession. Suffice it to say that such an agreement is still a long way off.

The biochemistry of milk wastewater stabilization has been the subject of numerous investigations since the early 1950's. Considerable effort has provided a general understanding of the mechanisms of milk decomposition and some general stoichiometric relationships have been reported.

The selection of biological reactor type and the mode of microorganism-wastewater contact are critical to the expected performance of the treatment system. Normally, the microorganisms may be held in suspension by aeration or mechanical mixing (suspended growth reactor) or they may be grown on surfaces over which wastewater is directed (fixed film reactors). The hydraulic regime produced in either reactor type will also dictate the apparent performance of the system. Thus, flow configurations described as plug flow, completely mixed, partially mixed with longitudinal dispersion, batch operation and complete-mixed-in-series are often used.

In practice, the design of biological wastewater treatment processes is often based upon empirical design parameters and rules of thumb. The magnitude of these parameters or standards of design are applicable primarily to domestic wastewater systems and should not be employed for design of dairy plant wastewaters. A fundamental approach to biological wastewater modelling in design for industrial wastewaters requires some experimental study. Where funds are limited, reliance upon information in the literature is second best, but extreme care must be taken to insure that treatability of the wastewater in question is realistically parallel to that being used as the model.

The following sections briefly describe a number of biological processes which have been employed successfully to treat dairy wastewaters. The performance of these processes, based upon past experience, is also presented merely to provide some idea of the range of performances expected under the design conditions. The strengths and weakness of each process for dairy wastewater treatment application are also cited.

Activated Sludge Process - One of the most popular methods employed for the treatment of dairy wastewaters is the activated sludge process. Flowsheets of several of the activated sludge process modifications appear in Figures 1a, 1b, and 1c. The process provides aerobic biological treatment employing suspended growths of bacterial floc. High concentrations of organisms, maintained by sludge return, reduce overall reactor size. The organisms are separated from the treated effluent by means of plain sedimentation.

Dairy wastewaters are normally treated in modifications of the conventional process flowsheet. Experience over the years has indicated that long hydraulic detention times, in the order of 15 to 40 hours, produce most satisfactory process results. In addition, a completely mixed flow regime appears most satisfactory providing an adequate dampening effect on the wide fluctuations in wastewater flows and strengths. The use of long detention time - completely stirred reactors (extended aeration, Figure 1c) precludes the use of special flow equalization facilities. Even pH fluctuations normally found in the raw wastewater stream will be significantly attenuated in this system.

Batch fill-and-draw activated sludge systems are also quite popular in the treatment of dairy wastewaters. These processes, too, normally operate over long periods of detention time and provide substantial dampening of flow and strength variations.

A very complete compilation of activated sludge performance for dairy wastewaters appears in the Ohio State Report (11). A brief summarization of selected findings from both recent reports on dairy wastewaters (8 ,11) are presented in Table II, along with ranges of design parameters.

It is apparent from examining Table II that a wide range of both influent and effluent BOD values is reported over a considerable range of detention times and volumetric loads. In general, superior performances are achieved at longer detention times although conscientious plant operation is paramount to successful performance. Two important design parameters, sludge age (pounds of volatile suspended solids [VSS] under aeration divided by pounds of VSS wasted or lost per day) and loading velocity (pounds of BOD applied per pound of VSS under aeration), are missing from this table. It is difficult to obtain reliable data on these two parameters from the literature, yet they truly define process performance. The active microbial population (often expressed as VSS in activated sludge systems) is an important variable, too, in describing overall system response. Absence of these values in Table II makes a clear delineation of expected performance a difficult task.

Based on past experiences, it appears that BOD removal efficiencies for dairy wastewaters in excess of 90 percent can be consistently maintained in extended aeration activated sludge plants. More germaine, however, is that effluent BOD concentrations below 30 mg/1 may be difficult to achieve consistently, even at long detention periods and sludge ages. Note that for raw wastewater BOD concentrations of 1500 mg/1, 98 percent BOD must be achievable. Of great importance in evaluating the consistent performance of the activated sludge process is the settling properties of the mixed liquor. Bulky sludge is not uncommon in plants treating dairy wastewaters, and the discharge of poorly settled sludge with the effluent will substantially elevate effluent BOD values. Even with extended aeration, as much as 30 percent of the effluent volatile solids may contribute to the total effluent BOD.

Oxygen requirements for stabilization of organic wastewaters in activated sludge are proportional to both the active biomass and the applied BOD removed. Laboratory or field analyses are employed to ascertain these requirements.

Oxygen for the activated sludge process may be provided by one of numerous types of diffused air or mechanical aeration systems. Oxygen

TABLE II

Performance of Biological Treatment Systems

Dairy Food Wastewaters

Type	Influent BOD (mg/1)	Effluent BOD (mg/1)	Removal of BOD (%)	Volumetric Load $\left(\frac{\text{LB BOD}}{\text{1000 cuft}}\right)$	Hydraulic Detention (Hours)	Number of Plants Reported
Selected Values Activated sludge ( )	620-1620	13-290	64-99	25-130	15-50	7
Activated Sludge ( )	--	--	24-99.6	---	---	100
Oxidation Ditches ( )	410-2150	3-165	74-99	4-41	27-320	10
Aerated Lagoons ( )	1000	20	98	---	---	1
Aerated Lagoons ( )	---	--	70-99	---	---	5

Performance of Anaerobic Treatment Processes on Dairy Wastewaters

Type	Influent BOD	Effluent BOD	% Removal BOD	Detention Time	Number Surveyed
Septic Tanks and Digesters	7000-500	300-400	50-87	3-10	12

transfer rates are dependent upon the aerator selected, the geometrical configuration of the reactor and the wastewater characteristics. This latter information is normally obtained through experimental studies. Diffused air requirements often quoted for dairy wastewaters are usually in excess of 1500 cubic feet per pound of BOD removed. Coarse bubble diffusion devices are commonly recommended for dairy wastewaters as they clog less frequently and require less maintanance than the fine bubble systems. Jet aerators, shear devices, surface turbines, pumps, draft-tube aerators, rotors and brushes are also popular. Oxygen transfer rates for these mechanical devices normally range from 3 to 4.5 pounds of standard oxygen per gross horsepower hour at standard conditions.

The production and handling of sludge from activated sludge plants treating dairy wastewaters are not well documented in the literature. Long aeration times (extended aeration) are recommended to destroy (endogenous repiration) a substantial portion of the sludge solids. Nonetheless, provision must be made to handle some sludge since a certain fraction of the sludge is nonbiodegradable and will eventually accumulate. Disposal of accumulated sludges from dairy wastewater activated sludges continues to be a problem as sludge handling may be very costly. Aerobic digestion of accumulated sludges followed by land disposal represents a desirable relatively low cost alternative.

The activated sludge process is less sensitive to temperature than other biological processes. Toxic effects of sanitizers and pH variations are usually effectively reduced through the use of extended aeration - completely mixed systems. Furthermore, the stability of activated sludge settling properties is more effectively enhanced in completely mixed systems employing low BOD loading velocities. Finally, long-term aeration employing sludge ages in excess of 10 days will normally produce highly nitrified effluents (a property likely to be desirable in the future if effluent standards are adopted for ammonia discharges). The removal of phosphorus by activated sludge systems is poor, normally ranging from 35 to 50 percent. Chemical precipitation, usually prior to final sedimentation, employing aluminum or iron salts will effectively remove phosphorus from final effluents and may serve to enhance settling properties of poorly settling sludge.

Cost of the activated sludge process are summarized in Table III based on data available in the Cost of Clean Water Series - Volume III, Profile 9 (1). All costs are reported as 1963 dollars. Unless otherwise noted, costs are based on a "medium" plant size with current technology. Capital costs are based on dollars per 1000 gallons of design flow, whereas operation and maintenance costs are based on pounds of BOD, and 1000 gallons of wastewater treated. Considerable caution should be exercised in placing emphasis on these figures since construction costs continue to rise rapidly and local conditions will fluctuate considerably from the national norm. In addition, the level of treatment efficiency required has not been stipulated in the compilation of these figures, but stringent effluent criteria may substantially elevate this figure. Finally, sludge disposal costs are often neglected in these figures, a fact which may lead to serious underestimates of true wastewater treatment costs for those processes generating high sludge volumes.

Oxidation Ditches - The treatment of milk wastewaters in oxidation ditches has been acceptable practice for a number of years in Europe. The oxidation ditch is an extension of the activated sludge process employing a ring-shaped circuit or ditch usually 6 to 10 feet deep (Figure 2). Aeration is provided by cage or brush aerators mounted at several points along the ditch in order to circulate flow around the circuit and to maintain sufficient velocity to keep solids in suspension. Baffling of rectangular lagoons with appropriately located flow directors will achieve the same effect. The oxidation ditch may operate as a continuous system or as a batch process. If operated in a continuous mode, a clarifier is incorporated as an integral part of the system.

Typical performance data for oxidation ditches appear in Table II. As was noted with the activated sludge process, considerable variation in loading, detention time, and process efficiencies are apparent. There is considerable evidence in the literature that at detention times in excess of 50 days and at volumetric loadings less than 15 pounds BOD/1000 cu ft effluent concentrations of less than 30 mg/l are achievable. High mixed liquor VSS, in excess of 4000 mg/l, are attainable with the configuration when employing sludge recycle. There is no evidence to suggest that this particular configuration will more successfully treat dairy wastewaters as compared with the extended aeration activated sludge processes at similar loadings. Costs of this process are likely similar to those for activated sludge although there is not enough operating experience in this country to provide reliable cost data.

Aerated Lagoons - Aerated lagoons are also an extension of the activated sludge process wherein no sludge return is normally practiced. As a result, the active biomass (VSS) in the lagoon is low, thereby requiring longer periods of aeration for comparable performance.

Data in the literature on the performance of aerated lagoon systems for dairy wastewaters is sketchy. Only three reports appear in the comprehensive survey by the Ohio State group (11), and 5 are reported by A.T. Kearney & Co. (8). (Table II). From this data there is evidence that current effluent requirements can be met by proper designed aerated lagoon systems. Design would most definitely be predicated upon careful pilot or laboratory scale studies. The experience of these authors is that aerated lagoons are a satisfactory alternative for dairy wastewater treatment. Currently a number of these systems for dairies are in successful operation in Wisconsin. An example of two of these systems will be presented later.

In most cases aerated lagoons are not vigorously mixed, resulting in sedimentation of suspended solids within the lagoon itself. These "facultative" aerated lagoons, therefore, remove organic matter through physical separation and anaerobic and aerobic stabilization. Mixing intensities normally required to prevent sedimentation in aerated lagoons require power inputs of approximately one order of magnitude greater than for oxygen dispersion alone (8 HP/MG vs 80 HP/MG).

On the other hand horsepower requirements for aeration are dependent upon the oxygen uptake rates, the required hydraulic detention time, and the oxygen transfer characteristics of the wastewater. In most instances the power required for aeration is less than that required for complete solids suspension and the engineer must determine whether the added power costs justify this added mixing capacity. In the majority of cases, dairies have not opted for this extra expense, a decision which appears sensible.

Aerated lagoons are normally designed as a series system. Most aeration is provided in the first cell, followed by a second or third cell of quiescent settling and stabilization. Normally lagoon depths of 10 to 15 feet are desirable although shallower cells are allowable for polishing or quiescent settling. Algal growths occurring in the quiescent cells may cause a deterioration in effluent quality and should be avoided, if possible, through proper outlet design, covering or filtration.

Aerated lagoons are temperature sensitive, producing poorer quality effluents in the winter months. Most engineers size aerated lagoons based on winter operations. The onset of warmer temperatures in the spring may result in increased biological activity in the anaerobic zones of "facultative" aerated lagoons. This activity often results in depletion of lagoon dissolved oxygen causing odors and loss of efficiency. Aerator designs should provide for this eventuality, especially in the poorly mixed lagoon systems.

Aeration is normally provided by either surface or submerged aeration equipment. In northern climates, surface aerators require considerable maintenance for ice removal and in retaining effective and consistent operation. Submerged units will not normally be effected by cold weather but orifices may clog (as with activated sludge) and mixing velocities are usually low.

Land requirements for aerated lagoons are high and most states require substantial distances be maintained between lagoons and residences. Because of long detention times, no flow equalization is required when employing lagoon systems. Sludge handling is relatively minor in most lagoon systems, although some provision may be made to dewater quiescent lagoons in the event of significant solid buildup. Anaerobic digestion normally maintains a relatively small sludge volume on the lagoon bottom.

Nitrogen conversion to nitrate is usually complete in aerated lagoons. Phosphorus removal is reported to range from 30 to 80 percent depending upon season of year. Phosphorus precipitation would account for this removal and resolubilization of precipitated phosphorus is likely to occur during certain periods of the year.

Costs for lagoon construction and operation are presented in Table III . Land costs were estimated at $300.00 per acre (1).

Stabilization Ponds - Stabilization ponds cover a variety of lagoon systems employed for wastewater treatment. As compared with aerated lagoons, stabilization ponds depend upon surface reaeration and photosynthesis for oxygen supply. For dairy wastewaters with strengths in excess of municipal wastewaters (300 mg/l BOD), lagoon surface areas or active algal populations must be extremely large. There is no practical method currently available in the midwest for maintaining algal cultures in the concentrations necessary to effectively treat most dairy wastewaters. Solar insolations are too low and winter conditions too severe for successful operation. Surface area requirements would appear prohibitive

TABLE III

Cost Comparisons for Wastewater Treatment - Base Year 1963+

Capital Costs - $/1000 gal*

	Creamery	Cheese	Condensed Milk	Ice Cream	Milk & Cottage Cheese
Ridge & Furrow	325	366	380	375	300
Spray Irrigation	927	1070	1070	1080	850
Aerated Lagoon	540	1170	100	78	1410
Trickling Filter	2030	5050	1350	5050	4050
Activated Sludge	1360	3360	900	3380	2700
LBS BOD/d	153	66	236	2.9	502
Gallons/d	17,200	4100	162,000	6400	19,600
Production-Lb/d	3,900	3400	46,200	890 gal/d	39,500 milk 630 cot.chs.

Operation & Maintenance**

	Creamery		Cheese		Condensed milk		Ice Cream		Milk & Cot.Cheese	
	$/1000gal	$/lb	$/1000gal	$/lb	$/1000gal	$/lb	$/1000gal	$/lb	$/1000gal	$/lb
Ridge & Furrow	0.18	0.02	0.20	0.01	0.21	0.14	0.21	0.47	0.17	0.01
Spray Irrigation	0.51	0.06	0.60	0.04	0.59	0.40	0.60	1.32	0.46	0.02
Aerated Lagoon	0.30	0.03	0.66	0.04	0.06	0.04	0.04	0.09	0.77	0.03
Trickling Filter	1.12	0.13	2.80	0.17	0.75	0.51	2.78	6.10	2.23	0.09
Activated Sludge	0.75	0.08	1.87	0.12	0.50	0.34	1.84	4.06	1.48	0.06

+ From "The Cost of Clean Water - Volume III, Industrial Waste Profile 9, Dairies, FWPCA, Washington,D.C. June 1967 (1)

* Cost per 1000 gal design flow

** Cost per 1000 gal total waste flow or per total pounds of BOD for most dairy wastewaters, being approximately 15 to 20 lbs BOD/acre/d. Thus, a dairy producing 500 lbs BOD per day would require at least 25 acres of land for stabilization ponds. In addition, at least one-quarter mile must be maintained between lagoon and the nearest residence.

The Ohio State Report (11) represents a compilation of performance of stabilization ponds. With few exceptions, effluent BOD exceeds that currently required by current effluent quality standards. The State of Wisconsin has stated that, if the New Federal Water Pollution Control Act is enforced as written, "treatment processes such as .... stabilization ponds would no longer be permitted as the sole means of treatment".

Based on the factors discussed above, there would appear to be little advantage in considering this method of treatment for dairy wastewaters.

Trickling Filters - The trickling filter process in contrast to suspended growth processes employs a fixed support medium to maintain the active organisms within the wastewater stream. In the past this medium has been rock, slag, or other low cost materials providing a large surface area per unit volume with a high void volume. Recently, numerous types of low weight, high specific surface plastic media have been developed for this purpose.

Organic matter associated with the wastewater is absorbed or adsorbed into the fixed biological film and is subsequently oxidized. Oxygen is normally provided by natural ventilation within the fixed bed although positive airflow may be provided to achieve more effective process operation. Contact time of the waste in trickling filters is normally short depending upon the application rate to the filter and the filter depth. Conventional filters are 6-8 feet deep whereas the plastic media filters may be constructed as high as 30 feet. Increased contact time is provided in some filters by recirculation of treated wastewater back through the filter. The mode of recirculation varies considerably from plant to plant.

Trickling filters are followed by clarification facilities in order to intercept and remove sloughed solids from the filter. Filter sloughing is a natural process and must occur in order to maintain an active biological mass on the media. Heavy accumulation of biological growth on the media surface will lead to filter clogging and poor oxygen transport.

There are numerous flowsheets currently employed that use the trickling filter process. The engineer selects a flowsheet which makes best use of the existing site and provides greatest operational flexibility for the wastewater being treated. Filters are normally designed based upon either hydraulic load (millions of gallons per acre per day MGAD) and organic load (pounds of BOD per 1000 cu ft per day) and they are normally classified as high or low rate in accordance with these loading parameters. Considerable controversy still surrounds the selection of the appropriate design parameter and its order of magnitude.

The performance of trickling filters treating dairy wastewaters has been summarized in the Ohio State Report (11). Examination of this extensive tabulation is confusing and of little real value to design engineers. As with the activated sludge tabulations, wide variation exists in both performance and magnitude of design parameters. Scatter diagrams prepared in the report (11) would suggest that neither hydraulic load nor organic load control process efficiency to any great extent. Process efficiencies range from less than 10 percent to 99 percent over ranges of hydraulic loading of from 0.14 to 20 MGAD and organic loads ranging from approximately 2 to 175 lb BOD/1000 cu ft day. Clearly, many of these reports are for roughing filters employed for pretreatment only. The A. T. Kearny & Co. Report (8) summarizes performance efficiencies ranging from 35 to 99.8 percent for 48 plants reported.

It is clear from this data that trickling filters, properly designed, may achieve current effluent quality standards. Indications are that plants designed at hydraulic loads less than 2.0 MGAD and organic loads less than 20 lb BOD/1000 cu ft/d may have a reasonable likelihood of success in achieving low effluent BOD. Such generalizations, however, are not sufficient that dairy food processors should employ them without considerable investigation. Currently, the State of Wisconsin has not favored trickling filtration as an effective means of secondary treatment. Winter operation often deteriorates effluent quality and covering of existing filters is strongly recommended in northern climates.

The proper ventilation or oxygen transfer in trickling filters is paramount to successful performance. Dairy wastewaters exert high oxygen demands as compared to municipal wastewater (per unit volume of waste) thereby putting a high demand on oxygen resources in the filter. Poor air circulation caused by heavy biological growths, clogged underdrains, and waste channeling will result in serious odor conditions, development of massive biological growths and deterioration in effluent quality. Positive ventilation procedures may effectively be employed to improve operation.

For this reason it is felt by these authors that the controlling design parameter in the case of high strength wastes is organic loading.

Recirculation of wastewater through the filter is often advantageous to eliminate excessive growths, reduce filter fly populations, and reduce odor. Cooling effects of recirculation are undesirable, however, during the cold winter months.

The use of plastic media filters for dairy wastewater treatment may prove to be most advantageous. More uniform void volumes and high specific surfaces will promote more effective oxygen transfer and wastewater contact with the biomass. In addition, considerable savings may be realized in land area when deep filters are employed.

Trickling filters handle shock loads moderately well although effluent quality may suffer for short periods. Whey should never be applied unless slowly added over long periods of time and filter design should account for this addition. Nitrogen conversion to nitrates will occur only on lightly loaded filters (usually less than 5 lb BOD/1000 cu ft/d) and phosphorus removals are poor, usually being less than 35 percent. Sludge produced in trickling filters, although less voluminous than that from activated sludge processes, must be subsequently handled. Anaerobic or aerobic digestion of sludges followed by land disposal are most commonly applied procedures.

The cost of trickling filter treatment appears in Table III. Plastic media filtration may be more expensive than indicated in this tabulation; however, a higher quality effluent will normally result more consistently than with conventional rock filters.

Rotating Biological Discs - The rotating disc process is a modification of the trickling filter process whereby the fixed biological film is rotated through the wastewater. First developed in Germany in 1955, there are now over 1000 installations in Europe alone. Research in the United States has developed a lighter, lower cost disc providing higher surface area. A large biological surface is provided by a series of closely spaced discs mounted on a rotating horizontal shaft. (Figure 3). The discs are slowly rotated at approximately 2 rpm through the wastewater while submerged to approximately 40 percent of their area. Organic matter is sorbed by the biomass on the disc and is subsequently oxidized in the presence of oxygen. A positive means of excess film sloughing is provided by the shearing action caused by the rotation of the discs.

The biological discs are normally staged so that a number of discs rotate within a given enclosed reactor cell. Wastewater passes from cell to cell through openings in the cell walls. This separation of reactors in series provides an advantageous development of specialized biological cultures for the waste constituents during each phase of treatment. Thus, by adding additional cells, one may achieve progressively higher levels of oxidation including complete nitrification of the wastewater. This cellular structure also reduces the effect of shock loads to the system. A clarification facility is required to remove sloughed biological solids from the discs.

Performance data on the biological disc in treating dairy wastewaters is scant. An example of one such application is given later in this paper. Design parameters currently used for the process are based upon a hydraulic loading (gallons per day per sq ft) and plant staging. Sludge production in these units are normally comparable to that in trickling filters and methods of handling and disposal parallel those discussed earlier. Costs of this type of treatment are still preliminary although it is apparent that operation and maintenance costs will be very low. The only power consumed is that used to rotate the disc shaft.

Anaerobic Processes - The anaerobic treatment of dairy process wastewaters has been practiced for many years in small dairy operations through the use of septic tanks. During anaerobic decomposition, lactose is rapidly converted to lactic acid, lowering the pH. In addition, fats and proteins are decomposed to amino acids, organic acids, aldehydes, alcohols, and other anaerobic intermediates. This phase of biodegradation is often referred to as acid fermentation and little BOD, COD or organic carbon "removal" is achieved. A second phase of biochemical reactions, methane fermentation, may also proceed, converting the organic acids to methane and CO_2. This gasification step subsequently "removes" BOD from the system as a gas. At "steady state", one reaction feeds the other resulting in a relatively constant pH and organic acid level. If conditions within the reactor become unfavorable for the methane bacteria (the most sensitive of the two groups of bacteria in this reaction system), acid build up will occur causing further deterioration of the process, a decrease in pH and a reduction in gas production. Successful anaerobic processes, designed for BOD removal, must develop a successful balance between these two phases.

Anaerobic processes normally have not been successful as complete treatment systems, since effluent quality is often poorer than that required by stream standards. The process does, however, offer a successful low cost process for wastewater pretreatment. Even if only the acidification step is achieved in the anaerobic process, considerably higher rates of aerobic stabilization may be realized with this pretreated effluent. More rapid decomposition of organic acids and anaerobic intermediates under an aerobic environment may result in smaller and more effective aerobic processes than could be achieved without this pretreatment.

Although quiescent holding tanks (septic tanks) have been used to treat dairy wastewaters, improvements in the anaerobic process have resulted in considerably better overall performance. Anaerobic contact processes, employing mixing with sludge return have proved to be successful in accelerating the conversion of organics to methane and CO_2. The use of anaerobic fixed film contractors (anaerobic trickling filters and biological discs) have also been examined.

Results of several reported experiences with anaerobic processes appear in Table II . Little data is available on anaerobic contact processes and fixed film reactors. The evidence indicates that approximately 50 percent of the applied BOD can be removed in quiescent digestion systems with little advantage gained beyond 4 days of detention time. Greater removals may be realized through more effective contact between the biomass and wastewater. Imhoff tanks may also provide more consistent results due to the separation of digestion and sedimentation processes.

The anaerobic process is sensitive to shock loads, temperature and toxic chemicals. Process efficiency may seriously suffer when temperatures of the wastewater drop below 10°C. Certain sanitizers, high concentrations of ammonia and numerous metal cations are toxic to methane bacteria. Anaerobic systems must be covered and should be ventilated adequately. Safety precautions should be taken owing to the presence of methane.

Costs of anaerobic systems are not readily available. Precast septic tanks range from $400 to $600 including installation up to 1500 gallon capacity. In most instances use of precast tanks in series is more economical than larger cast-in-place tanks. Operation and maintenance costs for anaerobic processes is dependent upon whether mixing is employed. Costs for simple septic tank operation range from $100 to $200 per year depending upon pumping and hauling costs. Low operation and maintenance costs are due largely to the absence of power requirements and the infrequent need to dispose of accumulated sludges.

Other Wastewater Treatment Alternatives

Irrigation - The use of irrigation as a treatment and disposal method for dairy plant wastewaters is most efficacious. It represents the best alternative if the proper type of soil is available in large enough acreage. Details of land irrigation practices have been covered in subsequent papers so that only a brief discussion will be presented here.

The success of irrigation methods depends upon the use of proper application rates and the effective pretreatment of the wastewater prior to disposal. Careful attention must be paid to the alternating of irrigation plots and provision and maintenance of the cover crop. High sodium concentrations may seal soil particles. Wastes high in particulate matter should be adequately screened prior to irrigation.

Recently, considerable success has been achieved by employing the soil as a biological filter. Permeable soils are underlain by tile fields which intercept the percolating wastewater. Nutrients are removed by the soil and its cover crop yielding percolates of high quality. Recycling or additional polishing of the percolate may be required prior to surface discharge.

Ridge and furrow irrigation of dairy wastewaters has met with little success in the upper midwest. Odor nuisance, standing water, and maintenance difficulties are attributed to this method of land disposal.

A summary of irrigation practices is detailed in the Ohio State Report (11). Costs for irrigation methods are presented in Table III. Costs for land are based on a value of $300.00/acre.

Filtration - The filtration of wastewaters normally provides a polishing step prior to final discharge. Filtration may be provided by microscreens or granular filtration devices employing diatomaceous earth or sand or mixed bed filters of materials such as anthracite and sand or activated carbon and sand. The state of the art of wastewater filtration is relatively new and considerable research continues to improve filtration techniques. Further details may be found in Culp and Culp (4).

Slow sand filters, 12 to 30 inches deep, employ filter sand for approximately one-half that depth underlain by coarse sand, gravel, and an underdrain system. Application rates of up to 3 gallons/sq ft/d are employed. Filter cleaning is employed when headlosses reach 8 to 10 feet.

The filter is then partially dried and the top layer of sand and sludge are removed. Clean sand is subsequently added prior to placing the filter back in operation. In general, slow sand filters are expensive to operate, require large areas and provide only moderate performance.

Rapid sand filters on sand or mixed bed filters are considerably more popular for tertiary treatment processes. Application rates of 3 to 6 gal/sq ft/minute are commonly employed. Cleaning of filters is provided by backwashing the filter with treated effluent.

In treating dairy wastewaters, the filtration step may be required as a polishing operation to achieve the desired BOD or solids concentrations. If the selected treatment process results in effluent concentrations high in degradable suspended solids (lagooning or even activated sludge processes) filtration may prove feasible. In most cases, filtration processes may be added to most process flowsheets at a future time to improve overall effluent efficiencies. If the treatment process achieves complete stabilization of the wastewater or if suspended solids are mineralized, filtration may not provide much advantage to the overall process flowsheet.

Chemical Methods - Chemical precipitation of dairy food wastewaters is not widely practiced primarily because of its high cost and its nominal effectiveness in organic matter removal. In some cases, wastewaters high in fats or colloidal matter might be effectively pretreated by addition of metal cations such as calcium, aluminum or iron or by polyelectrolyte additions. Voluminous amounts of sludge normally result with the metal salts requiring expensive methods of sludge handling and disposal. Polyelectrolytes may provide advantage heretofor not attainable with other chemicals. Small quantities of polyelectrolytes may affect substantial removal of solids at a reasonable cost. To date, the state of the art is not advanced enough to justify chemical methods as a reasonable alternative in the majority of cases.

Membrane Processes - The use of molecular sieves, electrodialysis, and reverse osmosis membrane systems has only begun. Considerable success for whey treatment has been predicted. Where water reuse or product recovery is feasible, these methods may prove successful. Costs at this time are high and normally discourage use in most dairy wastewater treatment schemes.

Carbon Adsorption - Carbon adsorption technology in the treatment of wastewaters has rapidly advanced over the past 5 years. Carbon adsorption systems are becoming competitive with biological treatment processes in the treatment of municipal wastewaters. Carbon systems are normally sized on the basis of mass of COD removed per mass of carbon. Carbon requirements for dairy wastewaters would be high and the cost of treatment is still not competitive with other alternatives. As effluent requirements increase, however, it is not inconceivable that carbon adsorption will be the competitive choice. A detailed discussion of carbon adsorption theory and application may be found in Culp and Culp (4).

Treatment Methods - Summary

In summarizing this discussion of treatment processes, a brief tabulation has been provided to assist the reader in a summary evaluation. Table IV has been prepared to give some guidance as to each process

TABLE IV

Comparison of Treatment Alternatives

Type	Effluent Quality BOD/Solids	Effluent Quality Ammonia	Effluent Quality Phosp.	Reliability	Cost Capital	Cost O & M	Land Reqmt.	Response to Shock	Economic Life (y rs)
Activated Sludge (Ext.Aer)	+++	+++	+	+++	H	H	L	+++	15
Oxidation Ditch	+++	+++	+	+++	H	H	A	+++	15
Aerated Lagoon	+++	+++	+	++	A	A	H	+++	20
Stabil.Pond	+	++	+	+	L	L	H	++	30
Trickling Filter	++	++	0	++	H	H	A	++	15
Biological Disc	+++	+++	+	+++	H	L	L	+++	15
Anaerobic Processes	+	0	0	+	L	L	L	+	20
Irrigation	+++	+++	+++	++	A	A	H	+++	20

Key:

+++ - Excellent
++ - Good
+ - Fair
0 - Poor

H - High
A - Average
L - Low

characteristic.

In selecting a treatment process, the engineer must consider carefully all alternatives open to him. The preliminary design may be based to some extent upon values reported in the literature. Final selection, however, should be based on treatability tests. This becomes more critical as effluent requirements become more stringent. The data presented in Table IV relates primarily to the effectiveness of these processes to achieve current effluent standards (i.e., BOD of 30 mg/l consistently). As effluent standards become more stringent, it will be more difficult to achieve "excellent" performance from many of these processes.

The processes discussed above were considered as separate treatment entities. In practice, it is wise to look at combinations of these processes so that advantages may be taken of the best parts of each. Thus, anaerobic pretreatment followed by aerobic polishing may provide a more economical alternative than the aerobic process alone.

Table V briefly summarizes the characteristics of a number of selected "tertiary" wastewater treatment processes. As pointed out earlier, selection of "tertiary" or polishing processes is dependent upon local effluent requirements, the current treatment process employed, and the characteristics of the treated wastewater.

In the next section, a brief discussion of three case histories are presented to give specific details of the types of design that may be employed.

TABLE V

Tertiary Treatment Processes

Effectiveness in Effluent Polishing

Process	Effectiveness in Removing:				
	Susp.Solids	BOD	COD	Nitrogen	Phosphorus
Microscreening	+	+	0	0	0
Sand Filtration	++	(+)*	0	0	0
Granular Carbon	++	++	++	0	0
Lime Clarification	++	+	0	0	++
Lime Clarification & Dual Bed Filtration	++	+	0	0	++

Key:

++ Excellent >80%

+ Good > 50%

0 Poor < 50%

*Depends op nature of Suspended Solids

CASE HISTORIES

1. Kent Cheese Co., Kent, Illinois - (3).

The Kent Cheese Company specializes in the production of Ricotta, Parmesan, Romano, and Mozzarella cheese. During the study, an average of 13,000 pounds of cheese were produced per day (excluding Sunday) producing approximately 17,000 gal per day of wastewater with a BOD of 270 pounds per day and a suspended solids loading of 85 pounds per day. Sources of wastewaters were from the rinses and washes associated with milk storage, transmission lines, vats and pasteurizer. Whey was collected and transported to another site for recovery.

The wastewater treatment system consisted of two equal volume aerated lagoons in series (Figure 4). Each 12 foot deep lagoon holds 955,000 gallons providing a detention time of 56 days based on design flow. The first lagoon was provided with thirteen-6 foot long 18 inch diameter Helixors (Polcon Corp) arranged in a pattern along the flat portion of the lagoon bottom. Three additional aerators are arranged in a triangular pattern near the inlet end. Two-240 scfm Gardner Denver rotary blowers provided the air supply for the lagoons. Water surface elevation in the lagoons was controlled by placement of a 4-inch cast iron riser pipe at a fixed elevation to maintain a 12 foot water depth.

The aerators were of the submerged air-lift type insuring operation throughout the year (Figure 5). Oxygen transfer studies conducted during a one-year study indicated that standard transfer rates ranging from 2.2 to 4.1 lb/HP-hr were achievable. Low mixing velocities were observed with the diffuser pattern and basin geometry employed in this lagoon. Very light accumulations of sludge (less than 2 inches) were noted after one year.

Results of lagoon performance based on BOD appear in Table VI . Wastewater temperature had the greatest effects on process performance. An overall average removal of 97.3 percent produced an average BOD concentration of 52 mg/l, ranging from 155 mg/l to 12 mg/l during the one year study. Poorest performance occurred during the winter months (Jan-Feb) but high oxygen uptake rates occurring in April through mid-July produced zero dissolved oxygen concentration in the primary lagoon causing odor and sludge rising problems. This unusually high activity has been attributed to rapid anaerobic decomposition of benthal soldis accumulated over the cold winter months.

During the one year study approximately 65 percent of the nitrogen was removed. Highest nitrate production occurred in warm summer months. Effluent total nitrogen concentrations ranged from 0.2 to 10.6 mg/l averaging 3.8 mg/l. Total phosphorus removals of approximately 50 percent were observed resulting in an average total phosphorus concentration of 21.6 mg/l.

Total capital investment for this plant in 1970 was $49,500 or $2900/1000 gallons of design flow. This is substantially higher than the 1963 costs estimated for aerated lagoons for cheese processes (Table III). Over the first year of the study the operation and maintenance costs were approximately $6000 resulting in unit costs of approximately $0.13 per pound BOD and $2.05 per 1000 gallons.

TABLE VI

Performance of Two Stage Lagoons - Kent Cheese Co.

Quarter 1971	Flow (gal/d)	Influent BOD (mg/1)	Influent SS (mg/1)	Prim.Lagoon Eff. BOD (mg/1)	Prim.Lagoon Eff. SS (mg/1)	Sec.Lagoon Eff. BOD (mg/1)	Sec.Lagoon Eff. SS (mg/1)	Overall Removal BOD (mg/1)	Overall Removal SS (mg/1)	Temp. °C
Jan-Mar	14,900	1,940	658	224	403	106	155	94.5	73.4	1
Apr-June	17,300	2,040	600	204	477	61	119	97.0	80.1	17.8
July-Sept.	20,000	1,530	547	122	239	21	43	98.5	92.1	21.7
Oct-Dec.	15,200	2,100	595	274	445	31	111	98.5	81.3	9.5
Average	16,900	1,910	602	209	395	52	108	97.3	82.0	--

2. Eiler Cheese Company, De Pere, Wisconsin (2,7).

The Eiler Cheese Company processes 30,000 pounds of milk per day into 3,000 pounds of American cheddar and Colby cheese. The treatment plant was designed to handle 3,000 gallons/day of wastewater, with a maximum of 5400 gallons/day, and a BOD load of 90 pounds/day (2000mg/1). About half of the milk handled is received in cans, the washings from which constitute the major source of wastewater. The balance of wastewater results from whey washing. Whey is separated and hauled to local farmers as a feed.

The wastewater treatment facility consists of three septic tanks connected in series followed by a four stage rotating disc system, a clarifier, a chlorinator, and a polishing lagoon (Figure 6). The septic tanks provide flow equalization, clarification of raw wastewater and digestion of recycled biological sludge. The three cells have volumes of 6,450 gal, 5,040 gal, and 1,400 gal respectively providing detention times ranging from 2.5 to 4.3 days. The rotating biological filters furnished by Autotrol Corporation were located in a vault 12 feet below ground level. The BIO-DISC (Autotrol Corp) system consisted of feed chamber, four-stage BIODISC unit, and clarifier (Figure 3).

The feed chamber is provided with a bucket feeder attached to the BIO-DISC shaft, thereby providing a constant feed to the biological unit. Each of the four BIO-DISC stages contain 22 molded polystyrene discs, 10 feet in diameter, providing a total area 13,800 square feet. The discs are rotated at a speed of 2 rpm (peripheral velocity of 62 feet per minute). Each stage provides a hydraulic detention time of 1.5 to 2.0 hours. The clarifier provides for overflow rates of 1800 to 2700 gallons/day/sq ft with sludge removal being provided by sludge scoops rotating at 4.5 rph. Sludge flows by gravity back to septic tank cell #1.

A 4.5 foot deep polishing lagoon with a 30 day detention time is provided to "polish" final effluent from the BIO-DISC.

Results of the performance of this treatment system for a 12 day period is presented in Table VII. It is apparent from examining this table that the septic tank did not provide the treatment expected. It was found that pH values dropped to values of 5.5 in cell 2 resulting in inhibition of methane bacteria. It should be noted, however, that recovery of pH did occur on the rotating biological filters and that excellent BOD removals were still achieved. BOD removal exceeded 95 percent on the BIO-DISC throughout the test period (12 days). It should also be noted that the "polishing" value of 30 day lagoons is questionable.

Burying of the BIO-DISC vault provided substantial insulation against cold winter temperatures. Minimum temperatures of the BIO -DISC mixed liquor never fell below 40°F even though ambient temperatures as low as -30°F were recorded. Several instances of shock loading were recorded during the 10 months of recorded data. Increased production resulting in peak discharges, raw milk spillage, and a whey dump were all experienced. The BIO-DISC unit continued to provide 60 to 75 percent treatment with full recovery after 2 to 3 days.

Capital investment for this process was $35,000* or $6,500* per 1000 gallons of design capacity. Operation and maintenance are minimal. The operating power for the disc drive was 0.5 HP and the clarifier scraper

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*Estimated based on current biomodule cost projection

TABLE VII

Performance of Septic Tank - BIO-DISC - Eiler Cheese Plant (7)

Date	Flow	Raw Waste			Septic Tank Eff.			BIO-DISC Eff.			Polishing Pond
		BOD	SS	pH	BOD	SS	pH	BOD	SS	pH	BOD
1971	(gal/day)	(mg/1)	(mg/1)		(mg/1)	(mg/1)		(mg/1)	(mg/1)		(mg/1)
Apr.19	3676	840	360	7.6	863	240	6.7	40	80	7.7	17
20	3411	720	280	7.6	810	320	6.6	32	20	7.6	27
21	3626	780	220	7.6	640	220	6.7	21	80	7.8	32
22	4405	1700	340	7.3	675	180	6.7	29	20	7.7	22
23	4703	1240	640	7.1	955	280	6.7	54	40	7.4	53
24	1540	1100	220	7.1	1060	160	6.7	65	40	7.5	53
25	761	705	140	7.2	870	120	6.5	53	20	7.6	50
26	3477	840	460	7.1	1000	100	6.6	30	60	7.5	48
27	3030	1540	240	7.2	970	240	6.6	48	40	7.6	46
28	3825	1150	240	7.0	1120	200	6.6	48	60	7.6	17
Avg.	3245	1062	314	7.3	852	206	6.7	41	46	7.6	37

was driven by a 1/6 HP motor resulting in an annual power cost of $100.00 based on $80 per horsepower year. Miscellaneous costs for septic tank cleanout and approximately 1 hour per month for servicing would cost about $200.00. Total annual operating costs, then, would be approximately $300.00 or $0.035 per pound BOD.

3. Afolkey Coop Cheese Co., Afolkey, Illinois (5).

The Afolkey Coop Cheese Co. produces approximately 8000 pounds/day of Italian Pizza cheese. Wastewater flows vary from 3600 to 9000 gallons per day with an average BOD concentration of 3500 mg/l. Wastewaters are generated from milk spillage and equipment washup. All milk is received in bulk trucks. Cooling water is separately discharged and whey is hauled to local farmers for livestock feed.

The wastewater treatment facility consists of an existing septic tank, appropriately modified, an aerated lagoon, a quiescent lagoon, and a sand filter (Figure 7). The existing 28,200 gallon three-celled septic tank providing an average hydraulic detention time of 3.1 days (maximum flow) was modified by the addition of paddle mixers placed within the first two equal sized tanks. The slow speed mixers were operated through a timer which regulated mixing for 15 minutes out of every two hours during times when the plant flow was off. This agitation provides intimate contact of anaerobic organisms with the raw wastewater. During periods of process operation, the mixers are shut off so as to allow maintenance of high concentrations of active biomass in the first two cells. The third cell provides for quiescent settling prior to discharge to the aerated lagoon.

The 10 foot deep aerated lagoon with a volume of 40,500 gallons provides a hydraulic detention time of 4.5 days at maximum flow. Aeration is provided by a 10 horsepower floating aerator located at the lagoon center. Sludge, pumped from the quiescent lagoon may be returned to the aerated lagoon to provide high biomass concentrations if required. Although originally uncovered, the aerated cell is now covered to reduce icing problems during the winter season.

The 10 foot deep quiescent lagoon serves to provide for settling and additional stabilization. This lagoon has a volume of 20,900 gallons providing 2.3 days of detention time at maximum flow. A baffled overflow weir is provided along the entire width at one end for effluent discharge to the sand filter. The tank is equipped with a hopper bottom to allow sludge collection and removal by pumping. This tank was initially covered to eliminate excessive algal growths during the summer. (Figure 8)

The sand filter was added to provide some means of effluent polishing. It consists of a 4 ft by 8 ft box approximately 12 inches deep. Approximately 6 inches of "filter sand" is underlain by coarse sand and pea gravel. Underdrain tile carry the filtered wastewater by gravity to the receiving stream. The wastewater is applied at a maximum rate of 11.7 gallons/hr/sq ft (0.2 gallon/min/sq ft). The filter is manually cleaned when the headloss exceeds approximately four or five feet. A small layer of old sand and sludge is removed and clean sand is added in this process. Cleaning is required approximately every three or four days although shorter periods of cleaning are required during periods of high solids overflow.

Data on the performance of this plant is sketchy; the results of two surveys are presented in Table VIII. The April 4, 1972, data was obtained when the sand filter was not in use. Results of septic tank performance are also presented in Table VII. These data were collected prior to installation of the slow speed mixers in cells 1 and 2. There is every indication from the data collected to date that the system will produce a highly stabilized effluent well below the 30 mg/l BOD currently required. It should be noted, however, that this performance is based upon flows considerably less than maximum. The best estimate of flow during the surveys reported was 3600 gallons per day, thereby resulting in detention times in the treatment units as follows:

Septic Tank	7.8 days
Aerated Lagoon	11.2 days
Quiescent Lagoon	5.8 days
Sand filter	4.7 gal/hr/sq ft.

The capital investment in this plant in 1971 was approximately $25,000 or $2780 per 1000 gallons of design capacity. Operation and maintenance costs include approximately $1440.00 per year for power, $150 per year for septic tank pumping two or three times per year, and $10 per day for plant maintenance. That amounts to approximately $4200 per year or unit costs of $1.27/1000 gallons or $0.004/lb BOD based on maximum design flow (9000 gallons per day at 3500 mg/l).

TABLE VIII

Performance of Septic Tank-Lagoon System - Afolkey Coop Cheese Co.

April 4, 1972

Est. Flow = 3600 gal/day
Est. BOD = 3500 mg/l

Final Effluent - No sand filtration
BOD = 15 mg/l
TSS = 16 mg/l
pH = 8.1
Nitrate N = 4.8 mg/l

October 20, 1972

Est. Flow = 3600 gal/d
Est. BOD = 3500 mg/l

Final Effluent - Sand Filter
BOD = 6 mg/l
TSS = 22 mg/l
pH = 7.6
NH_3-N = 0.13 mg/l
Kjeldahl-N = 2.91 mg/l
Nitrate-N = 14.5 mg/l
COD = 27 mg/l
Total Phosphorus-P = 16.3 mg/l

Septic Tank Performance (Prior to Mixing)

	BOD mg/l	T.S.S. mg/l	pH
Dec. 1968			
Cell 3	435	--	6.1
Jan. 1969			
Cell 1	2070	930	5.4
Cell 2	1245	440	5.6
Cell 3	>760	370	5.6
Feb. 1969			
Cell 3	815	560	---

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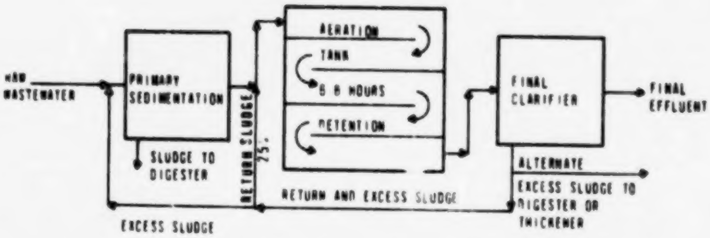
Figure 1a

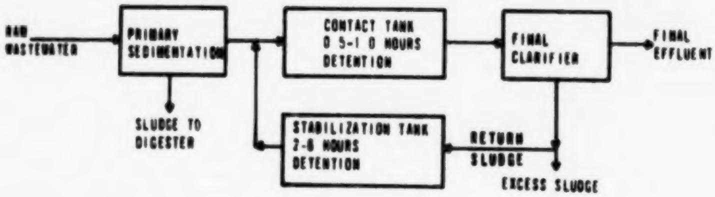
CONVENTIONAL ACTIVATED SLUDGE FLOW DIAGRAM


RAW WASTEWATER
PRIMARY SEDIMENTATION
SLUDGE TO DIGESTER
RETURN SLUDGE 25%
AERATION
TANK
6-8 HOURS
DETENTION
FINAL CLARIFIER
FINAL EFFLUENT
ALTERNATE
EXCESS SLUDGE TO DIGESTER OR THICKENER
RETURN AND EXCESS SLUDGE
EXCESS SLUDGE

Copied from Process Design Manual for Upgrading Existing Plants, EPA Cont. No. 14-12-933.

Figure 1b

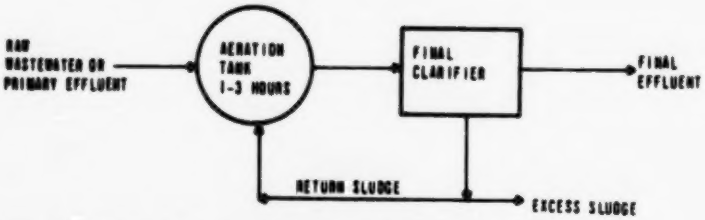
Contact Stabilization


RAW WASTEWATER
PRIMARY SEDIMENTATION
SLUDGE TO DIGESTER
CONTACT TANK 0.5-1.0 HOURS DETENTION
FINAL CLARIFIER
FINAL EFFLUENT
STABILIZATION TANK 2-6 HOURS DETENTION
RETURN SLUDGE
EXCESS SLUDGE

Copied from Process Design Manual for Upgrading Existing Plants, EPA Cont. No. 14-12-933.

Figure 1c

COMPLETELY-MIXED FLOW DIAGRAM


RAW WASTEWATER OR PRIMARY EFFLUENT
AERATION TANK 1-3 HOURS
FINAL CLARIFIER
FINAL EFFLUENT
RETURN SLUDGE
EXCESS SLUDGE

Copied from Process Design Manual for Upgrading Existing Plants, EPA Cont. No. 14-12-933.

Figure 2
Oxidation Ditch

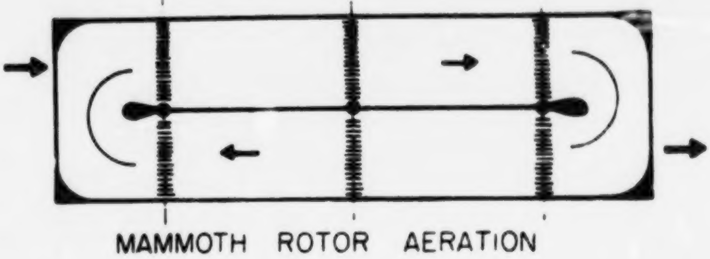
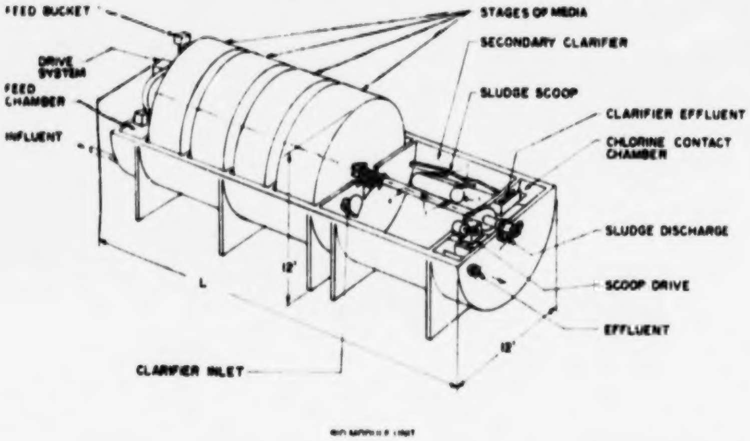
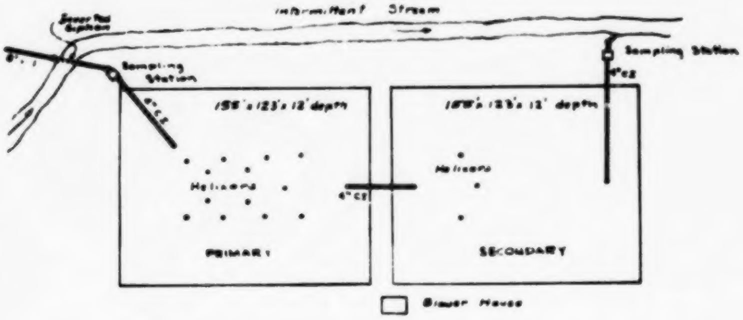

MAMMOTH ROTOR AERATION

Figure 3
Rotating Biological Filter


FEED BUCKET
STAGES OF MEDIA
DRIVE SYSTEM
SECONDARY CLARIFIER
FEED CHAMBER
SLUDGE SCOOP
INFLUENT
CLARIFIER EFFLUENT
CHLORINE CONTACT CHAMBER
SLUDGE DISCHARGE
12'
L
SCOOP DRIVE
EFFLUENT
12'
CLARIFIER INLET

Courtesy of Autotrol Corp., Milwaukee, Wisconsin.

Figure 4
Kent Cheese Company

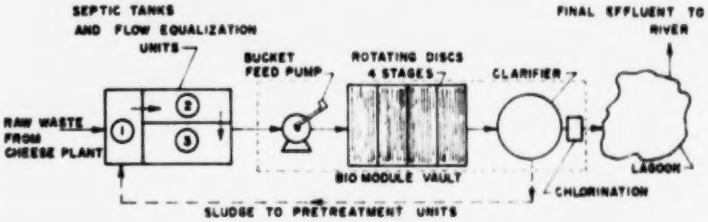

Intermittent Stream
Sampling Station
Sampling Station
Helixors
Helixors
4" CI
PRIMARY
SECONDARY
Blower House

Wastewater Lagoons

Figure 5
Kent Cheese Company Lagoons

Aerator Placement

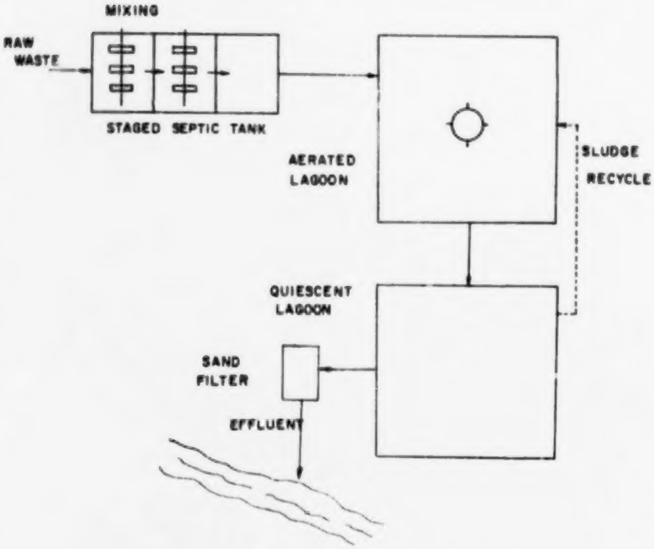
Figure 6
Eilers Cheese Company
BIO-DISC Treatment Plant


SEPTIC TANKS AND FLOW EQUALIZATION UNITS
BUCKET FEED PUMP
ROTATING DISCS 4 STAGES
CLARIFIER
FINAL EFFLUENT TO RIVER
RAW WASTE FROM CHEESE PLANT
1
2
3
BIO MODULE VAULT
LAGOON
CHLORINATION
SLUDGE TO PRETREATMENT UNITS

Courtesy of Autotrol Corp., Milwaukee, Wisconsin.

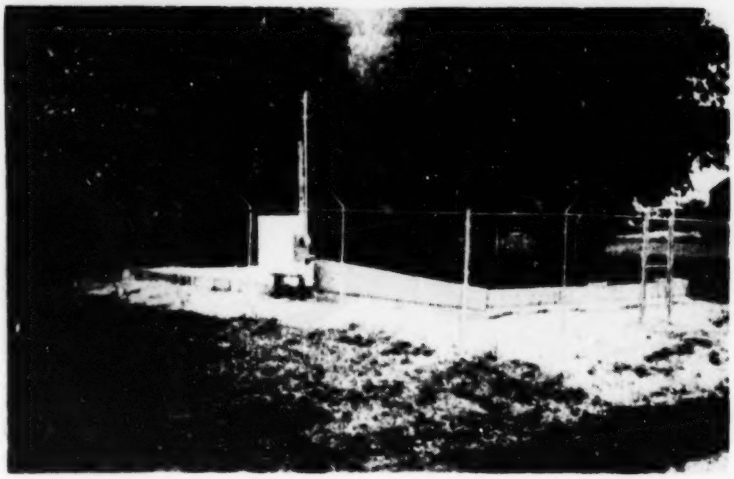
Figure 7

AFOLKEY CHEESE COMPANY


MIXING
RAW WASTE
STAGED SEPTIC TANK
AERATED LAGOON
SLUDGE RECYCLE
QUIESCENT LAGOON
SAND FILTER
EFFLUENT

Wastewater Treatment Process

Figure 8
Afolkey Cheese Company



REPRINTS ON

FOREIGN PRACTICE IN THE TREATMENT OF

DAIRY WASTES

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PRETREATMENT OF DAIRY EFFLUENT BY THE TOWER SYSTEM

A.1.2

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1. The high-rate biofiltration method for the treatment of trade effluents is becoming more and more widely used in industry, but until recently there were few installations of this type—i.e. the tower system—in dairies and creameries. Hence, there is little experience of this method of treatment of dairy wastes or of its relative merits compared with those of the more customary systems, which are largely based on percolating filtration.

2. Some preliminary observations were made on three installations which are in use in dairies in the United Kingdom.

3. At Creamery A the products manufactured were cream, milk powder, milk concentrates, cottage cheese and soft cheeses, at Creamery B they were milk concentrates, milk powder, cream and butter, and at Creamery C only yogurt, mainly of the fruit-containing type, was produced. In all three installations, a 2-tower series arrangement with intermediate settling was adopted as a primary or "roughing" treatment preceding secondary or "polishing" treatment by means of percolating filtration before final settlement and discharge of treated effluent to a waterway. At Creameries A and B adequate provision had been made for preliminary holding, in order to ensure as far as possible minimum variations in BOD loading during the working day. During non-productive hours arrangements had been made for re-cycling in order to maintain constant irrigation of the system. At Creamery C, due to increased output of product, the capacity of the pretreated holding tank was insufficient, with the result that there was little settlement and at times shock BOD loading of the system. Re-cycling was also adopted in this case.

4. Data relating to the three installations is given below.

Creamery	A	B	C
Design specification (m^3/d)	1,140	910	546
Maximum flow rate (m^3/hr)	47.7	38.2	54.6
Primary balancing	Adequate	Adequate	Inadequate
Primary settlement	Partial	Adequate	Inadequate
Operation flow rate (max) ($m^3/m^3/hr$)	0.048	0.062	0.070
Input BOD (p.p.m.)	1,200-1,800	800-1,800	1,000-1,200
Outflow BOD ex towers (p.p.m.)	250-300	70-150	200-300
Percentage reduction BOD	75-86	81-96	70-83

These summarized results indicate the comparative efficiency of high rate filtration installations at three creameries. They illustrate that the efficiency of two installations (at Creamery A and Creamery C) could be improved by providing adequate facilities for settlement prior to the "roughing" treatment, and that at Creamery C there are indications that the system will withstand shock loading.

5. The bios tower method has some merits as a first stage "roughing" process for the treatment of dairy effluents. Some of the advantages are the comparatively low constructional and operating costs, the relatively small ground area required and the inert construction materials. In addition the efficiency in reducing BOD loading is high with short recovery times after shock loading, and ponding cannot occur.

DISPOSAL OF DAIRY FACTORY EFFLUENT IN NEW ZEALAND

A1.2

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1. Problems of waste disposal have increased in recent years due to (a) concentration of manufacture in larger units, which has been made possible by tanker collection and amalgamation of dairy companies, (b) more stringent regulations against pollution. A number of rivers have been "classified," i.e. standards of water quality to be maintained in each section, depending on uses, have been laid down. The Water and Soil Conservation Act 1967 required all uses and discharges of water to be registered. Permits to discharge wastes into classified waters or rights to discharge elsewhere are subject to defined conditions designed to maintain the quality of the receiving waters. Discharge of wastes into small streams is therefore restricted much more than that into large rivers. Limitations on temperature rise may preclude the discharge into small streams of clean but warm water, e.g. condenser or cooling water.

2. A brief account is given of methods in use.

3 and 4. *Types of wastes.* Butter and milk powder factories offer only mild problems as wastes are limited to plant washings, although hot water from drying plants may cause problems where the volume of receiving water is limited. Whey from cheese and casein factories is a much greater problem. Casein plants also discharge wash water at least equal in volume to the milk received and containing whey equivalent to 10% of the milk volume.

Uses for whey. In the Taranaki area a lactose factory processing 325,000 gal of whey per day utilizes the whey from cheese factories in a large part of the province. Elsewhere pig feeding is the principal use. The pig population however, cannot be rapidly adjusted in numbers to correspond to the wide seasonal variation in milk production usual in New Zealand (a peak in October-November with a fall to almost zero in May-July). Consequently at least half the whey is surplus at the peak production period. Very little whey is dried as the returns make the operation uneconomic except for rennet casein whey.

Means of disposal. Only a few factories near large cities use municipal sewage facilities. As the wastes from a large casein factory can be equivalent in B.O.D. to those from a city of 100,000 the cost of a conventional sewage treatment plant would be beyond the means of a dairy company. A few coastal factories are able to discharge wastes into the sea. For the majority the best solution is irrigation on pasture land, preferably on a farm owned by the dairy company. A rate of application of 5,000-7,000 gal of whey equivalent per acre once in 14 days as suggested by McDowall & Thomas (1) has usually been found acceptable. The total volume of wastes per acre will depend on soil permeability and rainfall. Damage to pasture has usually been attributable to overdosing. With a well-managed system the increase in soil fertility and stock carrying capacity of the farm makes a substantial contribution to running costs.

5. Irrigation on pastures has been found to be the most economical means of disposal of dairy wastes in most parts of New Zealand.

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WATER POLLUTION BY FINNISH DAIRIES

A1.2

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1. In 1962 a new water law was passed in Finland. As a result, dairies started active water pollution research. Measures taken included: prevention of unnecessary discharge of milk residues or the first rinse water from butter, or whey, to the sewer, burning of separator slime, and restriction of phosphate-containing washing material to a minimum.

2. In 1967 the extent to which these measures had decreased the waste water loads from dairies was investigated.

3. The study covered 52 dairies of different types, representing 16% of the dairies and receiving about 30% of the milk produced in Finland. The studies were undertaken during the pasture-feeding period and again during the indoor feeding period. For sampling, the discharge pipe of the dairy was closed, and all the waste water was measured. From it, single samples were taken, and these were blended in proportion to the amount of waste water to give the test sample. Cooling water was not included. The results of the investigations are given in the table.

		Composition of waste water from		
		Market milk dairy	Butter factory	Cheese factory
pH		8.5	8.1	8.4
Conductivity	H_{18}/uS	608	611	1090
$KMnO_4$	mg O_2/l	258	340	641
Suspended solids	mg/l	271	354	306
Residue on evaporation	mg/l	1069	1158	2192
Residue on ignition	mg/l	349	395	801
BOD_5	mg/O_2/l	713	873	1045
Total N	mg N/l	52	51	52
Total P	mg P/l	12	13	15
$K_2Cr_2O_7$	mg O_2/l	1157	1316	2451
Org C.	mg C/l	434	512	723
Protein	mg/l	288	324	423
Sugars	mg/l	252	300	931
Detergents	mg TBS/l	4.0	2.7	2.6
Milk received 1000 kg/day		33.0	40.2	82.0
Waste water, cu m/1000 kg milk		1.61	1.63	2.3

The population equivalents (75 g BOD_5) per 1000 kg milk were 16, 17 and 30 for market milk, butter and cheese factories respectively. It appears that the measures taken for reducing the waste water discharge from dairies have been appropriate, especially in regard to butter and cheese dairies.

The total loading caused by dairies is about 1% of the waste water load of Finland, and the phosphorus loading corresponds to the waste water from about 60,000 inhabitants.

5. Some dairies have a purifying plant of their own, and attempts are also being made to purify most of the waste water from dairies in regional or other communal purifying plants, reducing the phosphate as well as the organic load.

COMPOSTING OF NON-FEEDABLE WHEY AND OF SLUDGE FROM EFFLUENT TREATMENT PLANTS

A.1.2

M. SVOBODA

Dairy Research Institute, Department of Water Management, Brno, Czechoslovakia.

1. Unless all whey from cheese factories can be regularly returned to farms for feeding purposes, a surplus may be held at the factory. It will deteriorate rapidly and must be disposed of into farm dung-water (1) or into isolated quarries or sandpits or on to pastures. There is always danger that such whey will be directed into the sewerage system or into streams.

Disposal of sludge from effluent treatment plants is also a problem. In large plants it is digested, or concentrated, precipitated and dried, or burnt. For small plants sludge is digested or dewatered on sludge beds, but digestion lowers the N content by only 40% and dewatering is slow and gives offensive odours.

2. Studies were made of the effectiveness of disposing of old whey by composting it on peat (2), and of the accelerated dewatering of sludge (3).

3. A site was selected which would not endanger spring- or surface-waters. Fresh fibrous peat meal was formed into a composting bed 70 cm high. Old whey was sprinkled over the surface. As the peat compacted the depressed crown of the bed allowed whey to be emptied into it. This was continued as long as the compost absorbed the whey. Absorption capacity was increased if the body of the compost was covered. When the limit was reached the compost was re-bedded and application of whey was continued.

Peat composts for dewatering effluent sludge were established in the subsoil. The sludge was applied to a pan formed in the crown. After 3-10 days, according to the weather, the dewatered sludge was removed, taking some peat with it. (Roofing of the beds increases their efficiency). This lowered the middle of the bed, leaving the sides. When all peat was removed from the middle, the whole was re-worked.

Several such beds were used in rotation. The peat was loosened in the new surface after every removal of sludge. The removed sludge was further composted separately.

4. By the composting, the pH of the peat was increased from 3.6 to 6.5-7.8, total N rose from 0.62 to 0.86—2.3% (on dry matter), moisture rose from 51 to 81%, and absorption capacity fell from 7.6 to 1.6. Application of whey caused a drop in temperature but after 2 days this rose to 50C.

There were no offensive smells. Under the conditions 1500 kg raw peat was sufficient for 40,000 l whey. Costs were one-sixth less than those for transporting the whey. If the compost can be sold as fertilizer at a good price, there are economies of 60% or more. The compost contains 0.8-3.3% N, 1.1-2.3% P_2O_5, 0.4-1.1% K_2O, 57-79% organic matter.

5. The peat compost beds provide an effective method of treatment. Their capital cost for a 60,000 l/day milk plant are half those for sludge digester or sludge beds.

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PRELIMINARY RESULTS OF COMPARATIVE INVESTIGATIONS ON TREATMENT PLANTS FOR FACTORY EFFLUENT

A.1.2

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The Government Research Institute for the Dairy Industry, Hillerød, Denmark

1. In chemical and physical respects, dairy effluent differs so much from ordinary sewage that conventional biological treatment plants are often considered unable to purify dairy effluent in a satisfactory manner unless it is first mixed with substantial quantities of sewage. However, in many cases this is not possible, and therefore some dairy factories may have difficulties in ensuring satisfactory purification of their effluent.

2. In order to solve the problems of such factories, information had to be sought on the best way of treating dairy effluent when unmixed with other waste waters.

3. Comparative investigations of the purification of dairy effluent were started in October 1968 using different types of plants constructed for this purpose near the Institute.

The dairy effluent was collected in an open levelling tank of 250 cu m, from which it was distributed to: (a) a recirculation filter containing 30 cu m of broken granite, and a clarification tank of 10 cu m; (b) a plant for alternating double filtration consisting of two filters, each containing 30 cu m of broken granite, and two clarification tanks of 10 cu m each; (c) an activated sludge plant with an aeration tank of 100 cu m and a clarification tank of 15 cu m; (d) a lagoon plant consisting of an anaerobic pond of 130 cu m followed by three aerobic ponds with a total surface of 500 sq m and a volume of 200 cu m.

4. The results of the first year were as follows: the average BOD_5 of the inflow was 517 mg $O_2/1$. During the year the hydraulic load of the recirculation filter was increased from 24 to 39 cu m/day, and the recirculation factor was reduced from 10 to 6. The organic load was 530 ± 140 g BOD_5/cu m/day. Removal of BOD_5 gradually increased from 70 to 90%. The hydraulic load of the alternating double filters was gradually increased from 42 to 58 cu m/day. The organic load was 440 ± 110 g BOD_5/cu m/day. The order of the filters was changed each week. In the course of the year the removal of BOD_5 increased from 70 to 90%. The hydraulic load of the activated sludge plant was gradually increased from 26 to 46 cu m/day corresponding to an increase of the organic load from 13 to 22 kg BOD_5/day. Removal of BOD_5 remained at a constant percentage of about 95. The precipitation of the sludge was periodically poor. Due to freezing and seeping the lagoon plant was not in regular operation. In a few cases of organic overloading the filter plants proved more resistant than the activated sludge plant.

5. When the sizes of the plants are taken into account it is evident that more effluent could be treated by recirculation filtration than by alternating double filtration with similar removal rates of BOD_5. The latter at no time proved entirely satisfactory. The activated sludge plant had at all times a satisfactory effect.

OXYGEN UPTAKE OF FACTORY EFFLUENTS

A.1.2

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1. The pollution of dairy effluent is commonly expressed by its 5-day biochemical oxygen demand, BOD$_5$. This is traditionally obtained by the dilution method. A new, less laborious, method consists of direct respirometric measurement of the oxygen uptake of the effluent. This principle is used in the Sapromat apparatus (J.M. Voith G. m. b. H.) which records hourly the amount of oxygen added to maintain atmospheric pressure above the surface of effluent in a flask.

2. This investigation was undertaken to determine whether the dilution method can be replaced by Sapromat-determinations for dairy effluent. The rate of oxygen uptake of dairy effluent and its constituents was investigated to provide information for work on treatment of dairy effluent by different methods.

3. Parallel determinations of BOD by the Sapromat-method and by the dilution method were made on effluents from various dairies and from treatment plants for dairy effluent. In addition Sapromat-determinations were made on various dairy products.

4. For effluents from various dairies, with BOD$_5$ values between 70 and 1700 mg O_2/1, the Sapromat-results were on the average 1.3 ± 0.2 times the results by the dilution method.

Fresh samples of dairy effluent after 1, 2, 3 and 4 days in the Sapromat showed oxygen uptakes of on the average 10, 50, 78 and 91% of the BOD$_5$, respectively. There was an induction period on the first day, maximum oxidation on the second and third day and thereafter the oxidation rate decreased. Continuation of the analyses for one week showed an increased in the oxygen uptake of about 15%.

If samples, properly seeded and with pH adjusted to 6-8, were kept some time before analysis a kind of maturation occurred, and the maximum oxidation rate was reached sooner, but after 3-4 days the stored and unstored samples showed almost the same oxygen uptake.

Sapromat-analyses on whey, skim-milk and whole milk gave average BOD$_5$ values of 58,000, 90,000 and 155,000 mg O_2/1, respectively. Continuing the analyses for one week showed an increase in the oxygen uptake of about 12, 15 and 18%, respectively. As the theoretical oxygen demands are about 2.8 g O_2/g fat, 1.7 g O_2/g protein and 1.1 g O_2/g lactose the results correspond quite well with the composition of the products. Compared with skim-milk the whey is decomposed faster and whole milk slower, indicating that, compared with protein, lactose is decomposed faster and fat slower.

Sapromat-determinations on effluents from plants purifying dairy effluent to different extents were on average 30% higher than the corresponding results by the dilution method. Extending the time in the Sapromat by one week increased the oxygen uptake by about 15%.

5. The BOD$_5$ values found for dairy effluent with the Sapromat were 1.3 ± 0.2 times the values found with the dilution method. The standard deviation is attributable chiefly to the inaccuracy of the dilution method, and the Sapromat-values can be considered quite reliable, although 30% higher.

The Sapromat-determinations showed that fresh dairy effluent is not decomposed appreciably by a short aeration. It is important to note that, although the oxygen uptake during the first days was higher for stored samples than for fresh ones, the final BOD$_5$'s of fresh and stored samples were almost identical.

BIOCENOSIS IN DAIRY WASTES PURIFICATION PLANTS **A.1.2**

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1. Several dairy waste purification methods have been successfully tested in Czechoslovakia. These are single-stage fermentation (1, 2, 3, 4), high trickling filter (5, 6), set of stabilization lagoons (7), assimilating (oxidation) pond (8), activated sludge (9), and oxidation ditch. A complete study of these processes included comparison of their economics (10).

2. The studies here reported were concerned with the chemical and biological aspects of the processes.

3. Analyses covering physical, chemical, bacteriological, and biocenological aspects were carried out at selected treatment plants. Results were compared and connections established.

4. In laboratory and semi-pilot single-stage fermentations, two types of biocenosis were found: yeast and flagellate. These arise and persist according to conditions of operation, particularly concentration of effluent and pH, suggesting that control of such factors could give higher efficiency. In full-scale plants there was also found an exponential relationship between the volume of introduced air and the count of *Diplostomatinae* flagellates.

In high trickling filters the biological films were compact and thick but through-flow was good. The films consisted mainly of zoogloea bacteria. Only rarely were filamental bacteria of the genus *Beggiatoa* not present, then being replaced by the mycelia of *Deuteromycetes*. Flagellates were common, particularly with heavy loading, which also affected infusorians. Best purification is accompanied by the development of mesosaprobic organisms, particularly infusorians.

Activated sludge in tanks or ditches typically contains the filamental bacteria *Sphaerotilus*, which disappear only with highly aerobic stabilization. Flagellates increase with heavier loading. Peritricha are an index of good purification and low B.O.D. of output. The relation between numbers of infusorians of families *Amphileptidae* and *Trachelidae* and the age of the sludge may be an index of the degree of aerobic stabilization of the sludge.

Stabilization lagoons have three reservoirs, the first or *bacterial* zone, in which the liquid is grey-black and putrid, is anaerobic. Biocenosis is hypersaprobic in winter, polysaprobic in summer. The second or *phytoplankton* zone is coloured by the microvegetation. Biocenosis is between poly- and alpha-mesosaprobity. Green algae and cryptomonades predominate. The third or *zooplankton* zone has clear water, develops only in summer and is needed for maximum purification. The crustaceoplankton, especially large cladocera are characteristic.

5. Study of biocenosis in waste water treatment can lead to more efficient operation.

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ECONOMY OF DAIRY WASTES DISPOSAL IN CZECHOSLOVAK DAIRY PLANTS

A.1.2

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1 and 2. We have tried, as far as it has been possible, to apply all methods of dairy wastes purification that would give statisfactory results in Czechoslovak dairy factories. In recent years we have endeavoured to evaluate these purification plants in the technological-economical sense (1). The aim of these studies was to find suitable purifying methods for future application under varying conditions in Czechoslovak dairy factories.

3. Eleven dairy effluent purification plants were studied during at least two seasons. Physico-chemical, bacteriological, hydrobiological and economic aspects were taken into consideration.

To make comparisons clearer, additional costs incurred because of unusual local conditions, e.g. distances, were deducted from capital expenditures. Operating costs were based on the average charge for electric power. As in Czechoslovakia the pollution of water streams is subject of payment of indemnities fee, the average indemnity charges actually paid by the factories in the period concerned served as a basis for the estimation of anticipated costs if a purification plant was not installed. In this way it was possible to estimate the return on investment.

The methods of treatment studied were:—intensive aeration, single stage fermentation, stabilization lagoons, tower trickling filter, activated sludge with mechanical aeration, assimilation pond and oxidation ditch.

4. It was found that the operating costs in each purification plant were mostly influenced by the cost of labour, by charges for electric power and by amortization of equipment. All these costs varied depending on the method and type of purification plant used. Amortization charges accounted for ca. 50% of all operating costs.

Relatively large differences were found in costs per 1 kg BOD_5 ranging from 0.47 to 9.52 Kcs and depending mainly on different organic load and volume of wastes actually treated.

Also depending on the method used the time for return of investment ranged from 3.5 years for the stabilization lagoons and activated sludge process with mechanical aeration to 17.5 years for the assimilation pond.

5. The following purification processes appeared from these studies as most economic:—stabilization lagoons, assimilation pond, activated sludge and oxidation ditch. Which of the processes should be used depends largely on the location of the factory and the topography of the available terrain.

The assimilation ponds and the lagoons require many hectars of surface area and the oxidation ditches some hundreds of square metres. This limits their use to factories situated in open country. The activated sludge process can be used, with minimal protective hygienic zone, in partly populated localities.

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BASIS FOR THE COSTS OF SEWAGE IN PUBLIC SEWAGE-TREATMENT

A.1.2

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1. Wastes and rain-water from dairies are often led to public sewage plants. These may be plants for sewage diversion and for sewage-treatment. The plants for sewage diversion consist of a network of pipelines for sewage and a similar one for rain-water. They may also only have one network of pipelines, through which sewage as well as rain-water is drained. Owners of these plants are communities, cities and sewage-associations.

2. For the drainage of wastes and of rain-water into public plants the dairies have to bear the actual costs incurred by them. This applies equally for the sewage of all other properties including private housing. Social factors are not taken into account. For the draining of sewage and of rain-water, annual payments, as well as single payments and annual payments are demanded; the single payments can be considered as annual payments in another form.

3. The costs, which result from the draining of sewage and of rain-water into the public plants are quite different according to whether pipeline connection or sewage-treatment is involved. With pipeline connection of waste waters, the costs are determined mainly by the length of the pipelines and thus by the size of the properties. The quantity of waste water influences the costs generally only very little. The cost for rain-water connections depend on the length of the pipelines and the size of the properties and also on the highest quantity of rain-water drained away in a second. The quantity of waste water treated is of importance in determining the costs of the sewage-treatment. When rain-water is also treated, part of the costs are attributable to rain-water. The nature of the wastes can influence the costs of sewage-treatment.

4. The standards for the calculation of costs, which are demanded from dairies for the connection of wastes and of rain-water to the public sewage disposal plants are very different. In some cases, the quality of sewage treated is used as the only standard. In most cases, a degressive cost calculation is also taken into account. The amounts charged for connection only are calculated on the same basis. According to these standards, the dairies are required to pay disproportionately high amounts, compared with private householders. The costs for sewage-treatment are often calculated according to the quantity of sewage. If there are additional costs based on the nature of the wastes, this will partly be taken into account by quantity factors.

5. Correct payments for the connection of wastes and rain-water to public plants, based on the actual costs incurred, can be determined if the total costs for public sewage plants are divided into the costs for waste water connection, rain-water connection, waste-water treatment and rain-water treatment.

The size of property is a main factor for determining waste water connection costs and the volume and nature of waste water are major factors in determining waste water treatment costs. In the case of rain-water, the size of property as well as the maximum quantity of rain-water drained per second are major factors. To this must be added possibly part of the costs of waste water treatment.

Effective techniques available

Biological treatment of dairy wastes

by Harvey Mitchell, Eng.*

Because of the nature of dairy wastes, biological treatment is more suitable than either physical or chemical methods. This article reviews several alternatives available for use in a modern dairy plant.

The dairy industry is a very diversified one as far as size of plants and type of products are concerned. Dairy wastes consist mainly of various dilutions of whole milk, skim milk, buttermilk and whey, together with washes containing detergents, nitric acid, caustic and other chemicals as well as sterilizers such as ammonia and javel water. Process washes of cheese, casein, butter and other products are also included.

Table I shows the average composition of different dairy products and *Table II* gives the average volumes and strengths of wastes produced in different types of plants.

Dairy wastes are generally high in dissolved organic matter and biochemical oxygen demand (BOD), which is defined as the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions. The standard BOD test carried out in 5 days at 20°C is used to determine the pollutional strength of wastes in terms of watercourses in which aerobic conditions exist. Domestic sewage has an average BOD of 225 ppm.

Importance of water quality

Water is extremely important to the dairy industry and the quality of the water used in washing milk handling equipment and in cooling dairy products has a direct bearing on the quality of the final products.

In order to meet the requirements of the modern dairy system, the water used should have the characteristics shown in the accompanying box.

CHARACTERISTICS REQUIRED IN WATER USED BY DAIRIES

1. **Sufficient quantity** — enough water must be available every day throughout the year. Failure of the supply, such as during a drought or freezing weather, has serious consequences in milkhouse sanitation. Sanitary care of milk handling equipment is an everyday must and when water is scarce, sanitation suffers.
2. **Clear, colourless, good taste, relatively soft** — soft water requires less detergent and gives better cleaning. Dirty water results in dirty utensils. Milk is susceptible to off flavours; poor tasting water does not help.
3. **Free from harmful bacteria, yeast, and moulds** — unsafe water may cause disease. Some bacteria cause rancid flavours in milk, while others can cause bitter, fruity and/or other unpleasant flavours. Yeasts and moulds also contribute to flavour defects of milk products.
4. **Non-corrosive water** — corrosion shortens the life of piping and water heaters. Copper and iron dissolved from piping by acid water may cause oxidized flavours in milk products.
5. **Nonscale-forming water** — scale may clog pipes, faucets, boilers and water heaters.(1)

The selection of a treatment plant depends on the type, size and location of the dairy.

Since dairy wastes are composed of soluble organic materials, biological treatment is more suitable than either physical or chemical methods.

The successful operation of a biological system depends on preventing the mixing of the wash waters with soiled milk as well as by-products such as whey and buttermilk. Standard practice is to recover these by-products which are then used as livestock feed, etc. The minimization of chemicals and detergents is also important, as excess alkaline or quaternary ammonium base detergents will raise the pH of the effluent and impair biological purification.

Suspended matters contained in the wash waters are usually removed by a fine screen. In receiving stations, provision is made to further remove the sand brought in by the milk wastes, especially during the winter and rainy season.

Because of the wide fluctuations in the waste volume and composition, a holding and equalization tank is necessary to stabilize the effluent flow and pH. The retention time of non-aerated holding tanks should be limited to 2 hours in order to prevent acid fermentation with a resultant increase in BOD.

A pretreatment consisting of a fine screen, degritter, aerated holding tank, and sedimentation can reduce the BOD by 15-20% and suspended matter by 60%.

TABLE I — COMPOSITION OF DAIRY PRODUCTS

	Water %	Fat %	Lactose %	Protein %	Ash %	BOD mg/1
Whole Milk	90—91	3.5—4	4.7—5.2	3.2—3.7	0.8	120,000
Skim Milk	90—91	0.1	4.9	3.6	0.8	75,000
Buttermilk	90—91	0.3—0.5	3.9—4.4 (lactic acid-0.6)	3.5	0.7	70,000
Whey	93—94	0.2—0.8	4.5—5	0.1—0.3	0.5—0.7	42,000

**Mr. Mitchell is manager of the Industrial Division of Degremont Canada Ltd., Montreal.*

To understand the special problem involved in biologically treating dairy wastes, it is important to study the metabolism of the two fermentable elements: lactose and proteins.

The lactose is in solution and therefore cannot be eliminated by precipitation or flocculation.

The proteins (casein, albumin, globulin) are in the form of suspended matter or colloids and can be eliminated by chemical treatment.

Lactose is a sugar having a formula $C_{12}\ H_{22}O_{11}$ which is transformed by fermentation into lactic acid according to the following reaction:

$$C12\ H22\ O11 + H20 \rightarrow$$
$$4\ CH3 - CHOH\text{-}COOH$$

Lactic acid is then transformed into different end products depending on whether aerobic or anaerobic (absence of air) conditions exist.

Under aerobic conditions, the end products are water and carbon dioxide:

$$CH\ 3 - CHOH - COOH + 3O_2 \rightarrow$$
$$3CO_2 + 3H_2O$$

Under anaerobic conditions, the end products are methane and carbon dioxide:

$$2CH_3 - CHOH - COOH \rightarrow$$
$$3\ CO_2 + 3\ CH_4$$

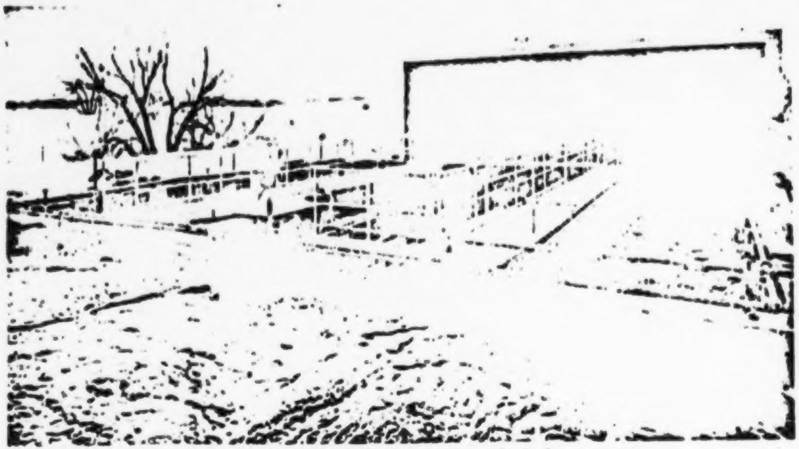
Aerobic fermentation of proteins results in the formation of amino acids and ammonia, which is then oxidized to nitrites and nitrates.

Anaerobic fermentation results in odorous products such as amines, ammonia, hydrogen sulfide and mercaptans.

Difficulties faced

The formation of lactic acid results in a lowering of the pH. Because the aerobic decomposition of proteins and lactose derivatives can only occur at a fairly neutral pH, waste waters, containing more than 1% lactose cannot be biologically treated by aerobic means.

Waste waters containing 1000-5000 ppm lactose are also difficult to treat by classic biological methods because the lactose induces the formation of a flora essentially composed of filamentous bacteria having a low purification capacity, and results in bulking of activated sludge plants and blocking of trickling filters.



Typical oxy-contact combined tank high-rate activated sludge system at St-Janvier, Quebec.

Biological treatment

The four conventional methods generally used are irrigation, lagoons, trickling filters and activated sludge.

Irrigation and lagooning can be used in certain cases but, generally speaking, they are not too economical because of the land costs resulting from the large surface area required (1000-2000 USG/acre/day) to handle the concentrated wastes.

Furthermore, the type of soil available and the climatic conditions may adversely affect the selection of this type of treatment.

The trickling filter and activated sludge processes are similar in principle in that both depend on biochemical oxidation of organic matters.

Trickling filter

The trickling filter contains a medium, such as crushed rock or a specially manufactured plastic, which becomes coated with zooglea, a viscous jelly-like substance containing bacteria and other biota. Under favourable environmental conditions, the bacteria absorb and break-down the suspended, colloidal and dissolved organic matter from the sewage.

Experience has shown that using a single filter results in a large biological growth which blocks the filter. BOD reductions of 75/80% have been obtained with organic loading of 40 lb BOD/1000 cu.ft/day. However, high-rate two-stage recirculating filters have produced greater than 90% BOD removal.

For example, two-stage recirculating filters handling an organic loading of 74 lb BOD/1000 cu. ft./day reduced the influent BOD from 1690 ppm to 140 ppm (92% reduction).

Since the efficiency of trickling filters is a function of the temperature of the waste, the quality of the

TABLE II — DAIRY WASTES

	Receiving Station	Bottling Works	Cheese Factory	Creamery	Condensery	Dry Milk
Volume: Gal. per 1,000 lb. milk intake per day	175	250	200	110	150	—
Total solids, ppm	1150	1500	1550	2400	2800	2400
Suspended solids, ppm	—	550	750	650	750	—
BOD, ppm	500	500	1000	1250	1300	500
pH	—	5	7	8	8	
Nature of waste	Whole milk washings	Whole milk washings	Whey, casein, washings	Butter-milk, washings	Spoiled-milk washings	Spoiled-milk washings

CHARACTERISTICS OF ACTUAL COMBINED SEWAGE TREATMENT PLANT

Loading:
Municipal — 1750 people x 0.17 lb BOD/person/day = 297.5 lb BOD/day
Creamery — 18,000 USG/day x 1300 ppm x 10^{-6} x 8.33 lb/USG = 195 BOD/day
Total : 492.5 lbs. BOD/day

Flow:
Municipal — 1750 people x 100 USG/person/day = 175,000 USG/day
Creamery — 18,000 USG/day
193,000 USG/day

plant effluent deteriorates under winter climatic conditions.

Although the effect of icing on the filters can be reduced by several methods, covering the units is considered mandatory.

Activated sludge method

Activated sludge is a proven method of treating dairy wastes with BOD reductions of 85-95%. The BOD represents food for microorganisms which break down the organic matter under aerobic conditions into waste sludge and end products such as CO_2 and H_2O.

For small installations, a total oxidation system can be economically used with a prolonged aeration period minimizing the wastage of sludge. An aeration volume of 480 USG is required for each pound of BOD.

As the size of the plant increases, it is less economical to consider total oxidation and the aeration time is therefore reduced.

For average size installations, an aeration volume of 120 USG is used per pound BOD. The excess sludge is aerobically digested.

For installations larger than 450 lb.BOD per day, the aeration volume is reduced to 60 USG per pound BOD. Primary clarification may be used ahead of the secondary activated sludge system. The waste sludge from the primary and secondary clarifiers can be anaerobically digested.

The activated sludge process can be carried in separate aeration and settling tanks or more economically in high-rate combined aeration-settling tank units.

Government regulations

Regulations concerning dairy wastes vary from province to province. The Quebec Water Board regulations of December 22, 1969 state the following:

1. It is forbidden to discharge dairy by-products such as skim milk, buttermilk, whey, etc. into a receiving body of water.
2. Because the BOD of the waste waters are 3 to 5 times that of domestic sewage, an aerated holding tank must be installed. This tank may not be required:
   a)—where the organic charge is less than 20% of the total organic charge discharged into a municipal or private sewer, or
   b)—where the wastes are discharged into a secondary treatment plant.

Joint treatment

There are many advantages to the consideration of joint sewage treatment with a municipality. However each case must be studied separately.

As an example of combined sewage treatment, a 'Rapid-Bloc' combined-tank high rate activated sludge plant was installed at Saint-Jean-de-Dieu, Quebec, to handle a combined municipal and creamery waste having the design characteristics shown in the accompanying box.

We can see from these figures that although the creamery wastes contribute 9.3% of the total volume, the BOD loading is 39.6% of the total.

The average BOD of the combined wastes is 305 ppm. The required effluent is 20 ppm which corresponds to a 93.5% BOD reduction.

The aeration volume is 28,200 USG (equivalent to 57 USG per lb. BOD) and the retention time at average flow was 3.4 hours.

The settling zone operates at 785 USG/sq.ft./day and has a surface of 252 sq.ft.

Excess sludge was air-lifted to an aerobic digester zone having a volume of 59,000 USG (10 days retention time).

Air requirements are 1600 cu.ft./lb BOD which gives 523 cu.ft./min. based on the elimination of 471.8 lbs BOD/day.

The effluent was chlorinated in a chlorination zone of 4150 USG (30 minutes retention time) before final discharge.

Operating results have been satisfactory and BOD and suspended solid reductions of over 90% have been obtained. ■

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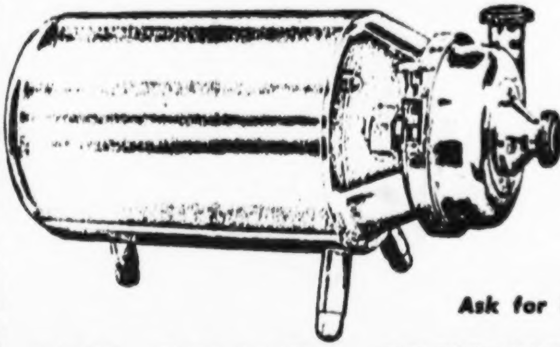

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Eighth paper

THE TREATMENT OF CREAMERY AND YOGHURT EFFLUENTS

BY A. J. GASTER
Technical Adviser, Express Dairy Foods Ltd.

Effluent treatment has received much publicity in recent years. In the dairy industry there have been technical advances in treatment systems, all pointing to a greater realization that pollution is very much today's problem. In the vast amount of technical literature on effluent treatment there is, however, very little information on the design and performance of effluent plants.

This paper sets out to compare the treatment system design of five creameries; four of which are concerned with a wide range of milk processing operations and the fifth solely with the production of yoghurt. It is necessary at this stage to draw distinctions between these two types of effluent for whereas creamery effluent contains fatty matter from operations involving milk reception, cream production, condensing, buttermaking, cheesemaking and drying, the effluent from yoghurt manufacture has comparatively little fat but a larger percentage of non-fatty solids and fruit pulp. I have made no mention of bottling dairies or creameries with operations outside those outlined, e.g. casein plant.

One obvious prerequisite of any treatment scheme is good housekeeping within the factory. The MAMPTAC (1969) report illustrates this quite clearly. Often the most difficult starting point in the design of a new effluent plant is assessing the volume and strength of the waste from the factory with any degree of accuracy.

Another relevant factor is the cost of water, often considered to be low in comparison with the expense of effluent saving schemes. Perhaps in the not too distant future water will be strictly controlled and the use of treated effluent to provide a reclaimed water supply for pre-rinsing, floor washing, etc. will become commonplace (Priestly, 1970; Anderson, 1970). There is also the associated danger that river authorities will ask for increasingly stringent standards which would result in a tertiary treatment system such as sand filtration, chlorination or even reverse osmosis becoming necessary.

What then is required to provide the basic information necessary to design a treatment system? Experience has shown that for each gallon of milk processed about 2·5–4·0 gal effluent are produced, the ratio for yoghurt being somewhat higher. This will establish, within limits, the expected throughput for a particular creamery. It is more difficult to find out useful BOD data as these depend largely on the particular processes involved. Creameries without cheesemaking operations tend to have lower average BOD, some actual figures being shown in Table 2.

Once obtained, the data on concentration and volume will be sufficient to give information about the design loading, expressed together as lb BOD or kg BOD. All other factors such as pH, temperature and maximum hourly rates are determined at a later stage. Sometimes, as was the case in two of the creameries under consideration, the need is not for an entirely new treatment plant but an extension or modification of an existing system. The ease with which the desired information can be obtained will of course depend on the metering and sampling facilities available. Often where an existing plant is in trouble and River Authority supervision has been close, the creamery will have kept stricter laboratory control and hence more data will be available.

It is now necessary to consider in detail the requirements for a treatment system discharging to a water course at Royal Commission standards. Dairy effluents are normally treated by a biological oxidation process whereby the pollutants are broken down to form a sludge of oxidized matter, leaving a comparatively clear liquor. The treatment is usually considered in three parts; pre-treatment (i.e. screening, fat separation, flow balancing, aeration), the roughing stage where the major part of the BOD load is removed, and the polishing stage which is the finishing stage prior to discharge to the river.

Initially the effluent discharged from the creamery is collected in a central tank. At this point screening of solid material will take place though often it may be carried out in individual process areas, e.g. curd removal in a cheese room. The liquor will flow forward to a balance tank, the aim of which is to distribute the daily flow evenly over a 24 h period.

Table 1 illustrates the volumes required for each of the 5 creameries, very approximately one third

TABLE 1
Comparison of creamery effluent plants

Creamery	*A*	*B*	*C*	*D*	*E*
Type of processing	*Cream, butter, condensing, drying*	*Cream, cottage cheese, drying, condensing*	*Cream, cheese, butter, drying, condensing, whey condensing*	*Cheese, whey condensing, drying*	*Yoghurt, (fruited type)*
Design throughput gal/day (m^3/day)	250,000 (1,140)	250,000 (1,140)	300,000 (1,360)	90,000 (407)	120,000 (546)
Actual throughput gal/day (m^3/day)	100,000 (455)	200,000 (910)	230,000 (1,050)	100,000 (450)	120,000 (546)
Balancing capacity gallons (m^3)	65,000 (296)	100,000 (455)	50,000 (227)	10,000 (46)	60,000 (273)
Roughing treatment	single stage flocor tower 600 yd^3 (458 m^3)	2-stage flocor tower 1,050 yd^3 (802 m^3)	single stage flocor tower 850 yd^3 (650 m^3)	4 small filter beds in parallel with aeration	2-stage flocor tower 770 yd^3 (590 m^3)
Polishing treatment	4 filter beds in ADF 3,240 yd^3 (2470 m^3)	3 filter beds in single pass	4 filter beds in ADF	2 filter beds in single pass 628 yd^3 (480 m^3)	2 filter beds in ADF 360 yd^3 (271 m^3)

of the daily throughput. For most efficient operation a plant should be run continuously at its maximum hourly throughput, the balance tank being of sufficient capacity to hold any liquid in excess of this amount. This balancing volume will be determined by the individual circumstances of each creamery and of course the times of cleaning of each section of plant. To obtain a constant irrigation or wetting, which is required for biological oxidation, the balance tank can provide a convenient point for recirculation of final effluent.

The use of balancing facilities will also aid the dilution of individual parts of the effluent load, e.g. detergent washes. In order to prevent anaerobic conditions and the tank's becoming septic, adequate aeration should be provided (Stoves, 1966). In the case of Creameries B and C, tanks that were previously used for aeration became the balance vessels.

It is interesting to note at this stage that in the majority of the treatment systems being described, pH or nutrient balance has been found to be unnecessary. Before any such system is contemplated the cost of adding a few gallons of this and that to an effluent plant each day must be borne in mind. Klein (1966) suggests a ratio of BOD to nitrogen and phosphorus for a waste water as approximately 100 : 4 : 1. This can usually be achieved with dairy waste.

The bulk of the total BOD load (lb BOD) is removed in the roughing stage. In four of the creameries under consideration high rate biofiltration is used. The comparatively recent development of plastics packing materials has opened a new field in the treatment of dairy effluents. It is not necessary here to describe the properties of this material, as Askew (1966), Chipperfield (1968) and the Water Pollution Research Laboratory (Ministry of Technology, 1968) have already described them. It is interesting, however, to compare the individual treatment problems in each creamery, with reference to Tables 1 and 2 (p. 29).

Creamery A had a new plant designed to treat 250,000 gal effluent using a single-stage biofilter tower containing 600 yd^3 of media. Whilst the plant is not up to its maximum loading, the applied load is 1·5 lb BOD/yd^3 under present conditions, design allowing for an increase to 6·25 lb BOD/yd^3. The reduction in BOD is over 80 per cent and has been as high as 95 per cent.

Creamery B had an existing installation which included a series of 9 aeration tanks in series. The system had become greatly overloaded due to increase in the manufacturing capacity of the factory. A 2-stage side-by-side biofilter tower was installed to overcome this problem and reduce the load to the subsequent filter bed stage. The tower contains 1,150 yd^3 of media, the ratio of media in the two stages being 2·5 : 1·0. With a throughput of

250,000 gal/day, the present load is 6·25 lb BOD/yd^3 and the reduction in BOD loading roughly 80 per cent.

Creamery C also had an existing plant which was suffering from overloading. To improve this position the existing roughing stage, a 30,000 gal tank with aeration, was converted to a balance tank and a new single-stage high rate biofilter was erected. The plant was designed for a throughput of 300,000 gal/day with 850 yd^3 of new filter media being employed. It is a little early at this stage to give operational figures for this installation. However, the design loading is 3 lb BOD/yd^3 and at present it is operating at about 85 per cent of this figure. The BOD reduction is 60 per cent.

The treatment plant at Creamery D is quite different from those already described. It consists of 4 small enclosed aerated filter beds as a roughing stage feeding 2 much larger filter beds as a polishing stage. There are rather inadequate balancing facilities and the average load of raw effluent is 990 lb BOD. A satisfactory final effluent is produced.

Creamery E is a factory dealing solely with yoghurt production and again a new plant was needed to relieve overloading at the local sewage works. The plant was designed to treat 120,000 gal/day of effluent using two high rate biofilter towers in series. Because of the nature of the effluent, provision was made for settlement prior to the roughing stage. Quite large volumes of sludge are removed at this point, the pH often being low due to the acidity of the fruit and product waste.

These high rate filters have at times been subjected to very severe overloading. For the first year of operation, balancing facilities were very poor but there was never any tendency for the plastics material to pond, and recovery from overloading was extremely rapid. The plant design loading was in the order of 1,500 lb BOD/day giving an applied load of 2·34 lb BOD/yd^3 day to the roughing stage. The BOD reduction is about 75 per cent. The question of whether a single or 2-stage high rate filter is used is debatable at this time.

The second or polishing stage in the treatment systems is relatively standard, percolating filter beds being used in all cases. In general terms the job of the roughing stage is to reduce the load to a constant level, say a BOD of 200–300. In a new plant then, the size of the filter beds is determined by this loading figure. For the treatment of milk wastes the Water Pollution Research Laboratory showed that by using two filters in series and alternating the feed each week, a consistently good effluent is produced. This method of alternating double filtration (ADF method) has become standard practice in the industry. The recommended load is 0·48 lb BOD/yd^3 day.

Creamery A has a comparatively large polishing stage and the design is such that the BOD of the waste from the high rate filter should be 500–600. Creamery C is comparable to Creamery A, using 4 large filter beds in ADF. With Creamery B, the situation is rather different; in order to modify the system it was decided to run the existing 3 percolating filters as a single pass. This has proved quite effective and, since the load at this stage has been reduced to a satisfactory level, the beds have recovered from their serious overloading and an effluent is produced to Royal Commission standards.

Creamery E has much smaller filter beds, the greater part of the load being removed by the high rate biofilter. It is not, therefore, possible to compare the ratio of load taken by each stage in the 5 creameries. What can be said is that each problem was assessed individually and the reasons for any particular design, whilst not seeming to be technically correct, took into account the particular local conditions.

In conclusion it is worth mentioning these local conditions and to comment on the satisfactory operation, cost, layout and room for future expansion. Creamery A discharges its waste into a stream which feeds an important fishing river in the West Country. Stringent conditions of maximum flow rate, temperature, pH and polluting matter were laid down by the River Authority. Though the capital investment in this plant was quite large, a good reserve capacity is available and the final effluent is consistently below 10 BOD. Compared with this, the treatment plant for Creamery E was built at a much lower cost and modified a year later. This plant has been a constant source of trouble, due to many failings, particularly in civil engineering, though most of these have now been corrected. This installation showed above all the importance of adequate balancing facilities, especially where the factory has erratic load conditions. The one enormous advantage of biofilter towers is their ability to handle overloads without their subsequent performance being impaired.

An interesting point to note here is the operation of the distributor arms on the percolating filter beds. Contrary to popular belief, these arms must rotate very slowly so that sufficient of the biological growth is washed away from the media to provide air passages (DSIR, 1959). The fact that all the operations described in this paper are essentially aerobic is basic to the treatment systems employed.

Creameries B and C are very similar. In both cases their treatment plants have been extended in the roughing stage very successfully with the high rate biofilter tower. The cost of both modifications was similar and comparable results are achieved.

These then are some of the facts accumulated from the operation of 5 creamery effluent plants.

TABLE 2

Comparison of effluent loads for each creamery

Creamery	*A*	*B*	*C*	*D*	*E*
BOD of raw effluent ppm	900	1,200–1,800	1,100–1,200	1,100	1,000–1,500
Highest BOD of raw effluent ppm	1,200	1,800	1,500	1,800	2,400
Load to plant lb BOD/day (kg BOD/day)	900 (408)	3,750 (1,710)	2,650 (1,200)	990 (450)	1,440 (654)
Load to biofilter lb BOD/yd^3 day (kg BOD/m^3 day)	1·5 (0·89)	6·25 (3·71)	2·5–3·0 (1·49–1·78)	Not known	2·34 (1·39)
% BOD reduction in roughing state	80–95	80	60	60–70	75–85
Load to percolating filter beds lb BOD/yd^3 day (kg BOD/m^3 day)	0·055 (0·026)	Not known	0·3 (0·17)	Not known	0·82–0·62 (0·28)
BOD of final effluent ppm	9	>20	15–20	<20	15–25

Time precludes the mention of other problems such as sludge disposal, smell, site layout, civil engineering, etc. I trust the information given will be useful, bearing in mind the limitations in the area of treatment considered.

Finally I would like to thank Express Dairy Co. for allowing me to present this paper and in particular Dr. T. R. Ashton for his advice and assistance.

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DISCUSSION

Dr. G. Chambers: At a cheese factory where a plastics biofilter is used as a roughing treatment we have experienced great difficulty with the build up on the medium of excessive deposits which interfere with circulation and ultimately cause collapse of sections of the medium. Has the speaker experienced this problem and can he suggest possible causes?

Mr. A. J. Gaster: We have had no trouble whatsoever, particularly in relation to our yoghurt factory which I have mentioned. They are overloaded but there never has been a build up. You would expect a good deposit of slime on these plastics packings; that is what is doing the good work. I would suggest that if you are having trouble, your problem is probably the water circulation and the manufacturers of these packings are only too helpful in providing information on these points, but you do have to have a certain minimum wetting rate. This is quite high: I think it is a figure of something like 30 gal/ft^2/min, but I cannot be sure. Unless you get sufficient water flow over these packings then you will not irrigate them and will not wash out this mire to give room for the air to get through.

Dr. R. Scott: With regard to Dr. Chambers' problem, I wonder if he is using too much chlorine?

I would like to ask what is the final BOD of these plants?

Secondly, we have not heard very much about the chemical demand. This is becoming more and more important. Some of the dairies, who were quite happy to dispose effluent into rivers, are now not quite so fortunate when some chemical firm built up-stream of the river discharges its effluent into the river, thus affecting the dairy effluent disposal, because the two react together.

Effluent disposal is more complex as more and more industrial concerns pour their waste into waterways whether it be waste chemicals or simply waste heat.

Mr. A. J. Gaster: We will aim, depending on the size of the biofilter which is the important thing, to get down to a BOD of the order of 200–300, but one of our plants has a much larger polishing stage – the plant is not one of our own design – and there the BOD at the outfall of the high rate filter is as high as 500–600, but we do in fact have a bottling plant with high rate filters, where we normally expect to get down to a BOD of 200–300.

As regards your second point on the chemical nature, I presume you are talking about COD. I think this is very much related to BOD itself. I have gone through these five plants very carefully and tried to assess their performance on as few parameters as possible. We have in fact not been able to provide information which is of much use to us, other than by the standard 5-day BOD tests, although the River Board does produce 4 h permanganate tests and COD; we do extensive testing using COD tests and try to obtain some correlation with this, because it is a much quicker test than the BOD test, and we did not get a very good correlation. I believe in fact an article was written in the Society's journal on this subject and we put this into practice but did not get a correlation.

In my experience of our creamery plants, we are not in general side by side with large chemical manufacturers, so we are fortunate. I have not come across this problem, although I heard mention of a brewery and a dairy getting together and mixing their effluent. This is obviously an excellent idea, if one of the effluents happens to be deficient of one of the minerals needed to provide satisfactory biological degradation. It is obviously much cheaper if you can combine and saves using additives, which can be very expensive.

Mr. N. L. T. Garrett: Can I ask to what extent management can be involved in solving effluent problems, for example, introduction of automated CIP, segregation of useful residues, recovery of fats, etc., and general housekeeping discipline in the factory before it has become effluent?

Mr. A. J. Gaster: I think it is very important indeed that management in processing is concerned with effluent treatment and is fully aware of not today's problems only, but tomorrow's problems. They tend to regard water as a commodity which is freely available at 15–20p/gal $\times 10^6$. Most of our factories use perhaps 100 thousand gal/day, 5–6 days/week, and if you add this figure up, it is quite astronomical. If you can talk in terms of this as a capital cost, it helps. I think the difficulty arises in promoting an effluent saving scheme when you have to be constantly on guard in a factory area, and this is why I would like to see some work done on tertiary treatment systems, where we can use reclaimed effluent and possibly chlorinated water supplies for such things as floor washing; but at present the work done does not show it to be economical. No doubt in future years it will become so, and then one can perhaps use water more freely. You said CIP schemes, well I hope we all use CIP schemes.

Dr. D. B. Stewart: I have been very impressed by the figures given by Mr. Gaster. I would, however, like to ask him how easy it is to obtain truly representative samples for BOD assessments?

Mr. A. J. Gaster: It is very difficult, I think, to obtain an accurate sample. What matters, as far as we are concerned, is that the discharge should always be less than that asked for by the River Board. It does not matter when they sample, if we are asked for Royal Commission standards, because we must have a BOD at any time of less than 20.

As regards samples of raw effluent or any stage needed, we tend to take a multitude of samples, bulk them and sample the bulk, and find this adequate. There are in fact flow measuring devices on the market which operate pyrostatic pumps at various times, say six times/h, take a small sample from the effluent stream into a bottle, (which could be stored) and obtain a sample again.

VOTE OF THANKS

Dr. J. G. Davis: Mr. President, in showing our appreciation of these excellent papers I think we should also pay tribute to those who have organized this meeting, as we have had a most interesting variety of subjects with something for everybody.

With regard to Mr. Booth's paper one has to admit that the position so far as mastitis is concerned is very much the same as it was 30 years ago, or even worse. I was concerned with a major investigation about that time, when we found that a third of the cows had some form of mastitis. More recently I was concerned with a smaller investigation and was appalled by the deterioration in the position of the problem generally. About two-thirds of the cows had mastitis and I have never seen such a variety of flora. The technique we formerly used for getting samples was quite hopeless, nine out of ten plates were crowded with colonies and altogether the position was very much worse. The explanation is anybody's guess; it may be the increasing stress on the cows, machine milking and increased yields, but personally I think that the far too wide and irresponsible use of antibiotics is a major cause of this deterioration. We have an interesting parallel here in human infections, because there we have many infections caused by Gram-negative organisms today, which previously were regarded as quite harmless.

Mr. Ross's subject is obviously one of much interest to us today, because we have an industry which is 70 per cent retail and this question of what is going to be the container of the future is the No. 1 problem in our industry.

I would particularly thank Mr. Gaster for his most excellent paper, a model if I may say so, and I hope that the Council will take note of this and perhaps arrange that we have at least one paper by a younger member, not forgetting the ladies, at these Conferences.

Ladies and gentlemen, would you please show your appreciation of our excellent speakers? (*Applause*).

SPRAY DISPOSAL OF FOOD WASTE

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Given the right conditions, disposal of liquid wastes by spraying on to agricultural land is an effective and cheap method. This article reviews work on this subject and discusses requirements for success

In common with other areas of the process industries, food processors are facing growing problems in disposing of their unwanted wastes. Waste treatment costs are rising as more stringent effluent standards are demanded before disposal of aqueous wastes to surface waters is permitted. In these circumstances, any disposal method which is cheap and which also avoids the risk of pollution of water-courses through oxygen depletion should be of interest to food manufacturers. If the evidence of a number of authorities is to be accepted, such a disposal method exists and forms the basis of many "ecologically acceptable" waste disposal installations. The method, which takes advantage of the "natural" biological filtration processes occurring when non-toxic liquid wastes of biological origin percolate into the ground, is spray disposal.

Land disposal of municipal wastes

The disposal of municipal waste liquors on to land has been practised in Europe for many years. In the U.K., two such sewage treatment methods were: (a) "broad" or "surface" irrigation where settled sewage was allowed to flow over gently inclined ground; and (b) "land filtration" where the ground was flooded with sewage. Both methods could be combined with the growth of suitable food crops on the so-called "sewage farm" though cash crop growth was more usually associated with broad irrigation methods.

According to Southgate[1], sewage treatment by land filtration gave effluents of good quality provided the soil was suitable. Porous soils — sand, gravel *etc* — allowed satisfactory treatment at effluent rates as high as 30,000 gal per acre per day. Less porous soils reduced the maximum permissible rates to nearer 2,000 gal per acre per day, while some soils such as stiff clay were unsuitable for this method of disposal.

Although land filtration needs less space than broad irrigation, ground requirements for both methods are high. The increasing cost of land in urban areas has, over the years, led to this method of disposal being superseded by the less space-demanding modern sewage plant. With the ever-increasing need for satisfactory disposal of municipal waste waters interest in land disposal has been revived. The possible disposal of municipal wastes to forest land is under active consideration. After "living" biological filtration, as waste waters percolate through the ground, purified water is returned to ground-water reservoirs. Parizek *et al.*[2] describe such an experimental disposal system capable of disposing of 450,000 gal of liquid per day.

Comparison of municipal waste and food wastes

Although the disposal of sewage to land has for long been practised, a relatively new development is the disposal of liquid industrial wastes by spraying on to land. When associated with crop growth, this disposal method is gaining popularity under the banner of "spray irrigation". Not surprisingly, when remembering the similarities between many food wastes and domestic sewage, it is the food industry, particularly the canning and dairy processing sections of the industry, that has pioneered this seemingly straightforward and inexpensive method of disposing of unwanted waste liquors.

Both food wastes and domestic sewage are likely to be complex mixtures of carbohydrates, proteins, fats and inorganic nutrients. It must be remembered, however, that food processing wastes are considerably stronger than domestic sewage. The former contain large amounts of organic matter and can have very high values of BOD (biochemical oxygen demand). Although only to be taken as indicating orders of polluting strength and not as rigid values, the figures in the accompanying table indicate the wide range of values of BOD encountered in some sectors of the food industry (typical figures for domestic sewage are included for comparison).

Table 1. Typical BOD values

Waste	BOD_5 (mg/1)
Fruit and vegetable preparation	500-2500
Canning	2000-4000
Dairying: whole milk	110,000
milk washing	75-1500
Meat processing	200-3000
Blood	165,000
Domestic sewage	200-400

If similar ground conditions to those experienced with "land filtration" disposal methods for sewage are to be expected following irrigation with food wastes, then dilution may be necessary.

Advantages of spray irrigation

According to Gurnham, the first application of spray irrigation to industrial waste disposal was in 1947, at the Hanover Canning Company in Pennsylvania[3]. Since that time many more spray disposal installations have been successfully operated, although mainly in the canning and dairy processing industries. Scott[4] for example reports that in 1963, in Wisconsin alone, 32 out of 107 vegetable and fruit canneries operating in the State were using spray disposal. Reasons for adoption of the method in these fields are not difficult to find:

(a) A purpose built conventional waste treatment plant entails high capital expenditure. For ideal operation of such a plant a requirement is the provision of a steady flow of waste liquors of constant strength. Furthermore, for maximum return on the investment, the plant should be operated at its optimum capacity throughout the whole of its life. Canning and dairy processing are two areas of the food industry whose production schedules are necessarily remote from these idealised conditions. By the very nature of their raw materials, fruit and vegetable and dairy processing operations are highly seasonal. Under these conditions, expensive plant to be operated for short, highly intensive periods becomes difficult to justify.

(b) Both cannery and dairy processing installations are likely to be sited in country areas where land is relatively cheap. The combined costs of land plus spray irrigation equipment when weighed against the costs of a purpose-built waste treatment plant, working at well below its maximum capacity for part of its life, are likely to favour spray disposal, even when allowance is made for levelling and draining of the site. This becomes particularly true if it is possible to recover part of the costs of the operation, by expeditious use of the grass or other crop raised on the spraying grounds.

(c) Though opinions differ, there is some evidence that the spraying ground benefits from resting periods, when spraying ceases. Again it is seasonal processing operations that are best suited to this type of operation.

First considerations for spray disposal

An essential prerequisite when considering spray irrigation as a possible method for disposing of food wastes is the availability, at acceptable cost, of an adequate area of land not too distant from the factory site. The area required depends on a variety of factors, including soil drainage characteristics, nature of crop cover, climate-temperature, rainfall *etc*. The required area increases as the volume of waste to be disposed of increases.

The land should be relatively flat, any slopes being less than 5-6 per cent to avoid drain-off with consequent risk of pollution to nearby watercourses. The ground should also be even to avoid ponding, so some initial levelling may be required. Both soil and subsoil should be fairly porous. Open-structured sandy soils permit considerably higher liquor application rates than do heavier clay soils. With less porous soils, tile draining might be necessary to carry away excess water during wet periods.

A geological survey must show the absence of cracks and fissures in the underlying strata that could lead to contamination of underground water sources. Seabrook[5] however, reporting on studies of BOD values of percolating vegetable waste liquors at different levels in the ground, suggests that some 96 per cent of the organic content of the waste water is removed within the first 4 inches of the surface. Under these conditions the risk of contamination of ground-water sources is slight.

Since strong winds can carry finely-divided liquid droplets considerable distances the spraying ground should be protected by some sort of windbreak if windage could create a nuisance in surrounding areas. Spraying into woodland overcomes this problem and one U.S. cannery has, since 1950, been satisfactorily disposing of some 8 million gal per day of vegetable waste liquors in this manner[4].

Importance of crop cover

Purification of waste water by land disposal is considered to be predominantly a biological process. The greater proportion of the waste is subjected to biochemical action as it passes through the soil. Besides removal of water by percolation into the ground, some is also lost by evaporation.

The volume of liquor that can be applied to a given area of land without ponding or other deleterious effects can be significantly increased by the presence of a crop cover. Besides removing more water by transpiration and using organic matter as a source of nutrients in its growth cycle the crop cover also prevents erosion of the soil. Erosion, with consequent compacting due to the impact of water droplets from the sprays, significantly lowers the drainage rate through the soil. The roots of the crop cover may also help to maintain an open structure within the soil, thus aiding percolation.

For a crop cover intended to yield some sort of return, as opposed to spraying into woodland, the most suitable cover is often said to be pasture grass[6]. Agricultural crops besides being more sensitive to over-watering and scorching are more easily damaged when changing the position of spraying heads. Controlled dosing over regulated periods does yield saleable crops however. Nelson[7] describes a spray irrigation system disposing of vegetable waste liquors on a 110-acre farm. A crop rotation system based on peas, sweetcorn and hay was used, the resulting crop of peas and sweetcorn being canned on site.

Obviously a knowledge of crop husbandry is valuable when considering spray irrigation schemes, since it may permit the selection of crop-cover for specific applications. When using pasture grasses disagreement exists as to whether shallow or deep-rooted grasses are more suitable. With less porous soils, thicker and deeper root systems might, by maintaining an open structure to a greater depth, be expected to aid percolation. On the other hand, however, with open porous soils, the thicker root system may lead to a decrease in percolation rate since the flow rate of fluids through porous beds is inversely proportional to bed thickness. In this case shallow-rooted grasses adequate to protect against impact compaction would be more suitable.

In some spray disposal applications striking changes in flora have been observed following extended spraying. Seabrook[5] reports on a woodland spraying area originally consisting of mixed oaks with a ground cover of mountain laurel, blueberry, blackberry, dogwood and holly. After three years of irrigation the ground cover had been replaced by a dense growth of climbing hempweed, elder, nightshade and other herbaceous plants. Some of the plants had grown to heights and thicknesses several times those of the same species in unsprayed areas. More recently Sopper[8] found that spraying municipal sewage into woodland also caused significant changes in herbaceous ground cover. Height growth, density, and dry matter production were all significantly increased. The diameter growth of mixed hardwood trees in the spraying area was not affected at lower liquor application rates (2.5cm/week) but was significantly increased at higher rates (5 and 10cm/week rate). It should be noted that 2.5cm/week is equivalent to a volumetric discharge rate of about 22,000 gal per acre per week.

Equipment requirements

Relative simplicity, hence low capital and maintenance costs for equipment, are advantages offered by spray disposal. Conventional crop irrigation equipment and suitable land are almost the only requirements. A constant rate of flow to the pump feeding the self-activated revolving spraying heads should be provided by using a suitable sump tank. This tank is not a septic tank and should be kept small to avoid possible anaerobic decomposition and resultant odour problems.

To avoid blockage of pipe lines and spraying heads, larger solid particles should be removed by screening prior to spraying. Minimum screen sizes of 20 to 40 mesh (openings per inch) are recommended[3]. For small installations, easily removed basket screens are adequate but with larger installations rotary or vibrating screens may be necessary.

With some installations the solids removed from food wastes are often suitable for animal feeding. For effective application the position of the spraying heads needs to be moved frequently. Normally a fixed main line transports waste to the irrigation site while lateral lines are used for distribution from the main line. Lightweight plastic or aluminium pipes should be employed for the lateral lines. Thirty foot lengths of aluminium pipe joined by quick acting automatic joints, easily dismantled, moved and reassembled by one man, are used in an installation in Ireland[9].

Composition and strength of waste liquors

The composition and strength of the waste liquors must be acceptable to both the cover and to the soil. The pH, mineral and organic content must not be injurious to the growth of the particular cover. The maximum rate of application of a liquor will depend on its strength. High concentration wastes can lead to scorching and damage of the cover when sprayed for extended periods.

Alkaline cleaning agents are extensively used in the food industry. Sodium ions in these agents can replace calcium in the soil by ion exchange causing soil disintegration and compacting. The porosity of the soil falls and in consequence the rate of spraying must be reduced if ponding is to be avoided.

When food wastes are to be applied to clay soils McKee[10] recommends that the sodium concentration should not exceed 100mg/l. To avoid any odour nuisance the waste liquor must be fresh and be sprayed on to the land before anaerobic decomposition can take place.

Rates of application

Permissible waste liquor application rates depend on the type of soil, the crop cover and the climatic conditions in the spraying area. Penetration tests will provide suitable rates for specific purposes. Figures published in the literature provide some guide to application rates actually experienced in practice.

Work done by the U.S. Soil Conservation Service[11] suggests maximum rates of application to soil carrying a crop cover varying from 2 in/hr. (approximately 45,000 gal per acre per hour) for thick uniform layers of coarse sandy soils, to 0.15 in/hr. (3,400 gal per acre per hour) for heavy clays and clay loams. These figures are reduced if rainfall is likely to be heavy.

Bell[12] reported the application of 0.33 in/day of a cannery waste on to silt loam carrying a cover of alfalfa. The plant operated for 180 days of the canning season giving a total application of 60 inches on some 40 acres of land.

Again with cannery wastes Seabrook[5] suggests a rate of slightly less than 1 in/hr for a sandy natured soil having gravelly underlayers. He points out that the area under the spray nozzles receives considerably more liquid. In penetration tests comparing spray disposal on to tilled land with that into unploughed woodland, Seabrook further found that in the former case, the ground was "saturated and soupy" to plough depth after an application of 2 inches of water. Mixed oak and pine woodland on the other hand took up 56 inches of water at a rate of 6.5 in/hr without becoming saturated. In these tests the woodland area received 150 inches of water in 10 days with no sign of saturation.

Considerably lower application rates are reported from trials in Holland[13] on the disposal of dairy wastes by spraying on to pasture land. This work ggests that sandy soils can receive 8 to 12 in/year whereas peaty soils can accept up to 20 in/year. At these rates high yields and improved quality of the grassland resulted. Higher rates lead to deterioration of the grassland and in the case of sandy soils application of some 33 inches of liquid per year led to waterlogged conditions.

Work carried out in New Zealand on the disposal of dairy effluent to pasture land suggested application rates as high as 12 inches per irrigation of 8 hours duration with well-drained sandy soils[14]. With heavy clays the rate fell to 0.15 inches per irrigation. This work recommends against spraying on to heavy clay soils during periods of heavy rain. After spraying, a 14 day rest period was allowed before grazing or harvesting of the grass crop. This was followed by a further 10 days recovery period, thus spraying took place for 1 day every 25 days.

Nearer home, Barfield[9] reports the disposal of 18,000 gal/day of dairy effluent on to 30 acres of land in Ireland. Eleven spray positions are in use, each area being sprayed for 2 days followed by a 22 day rest period. Though the soil is said to be fairly heavy, according to Barfield this volume of waste was "easily and efficiently handled by the irrigation scheme, which has entirely solved the twin problems of effluent disposal and pollution".

Causes of failure

Over-dosing is a major cause of failure of spray irrigation schemes. Crop cover damage, the deterioration of soil structure leading to ponding and odour problems, and contamination of ground waters if the natural biological filtration process is not completely effective with over-strength liquors are some troubles that can arise through the application of liquors of too high a concentration. A correctly balanced waste liquor flow should prevent these difficulties.

A more common cause of over-dosing failure is the application of acceptable strength liquors at too high a rate of flow for the area of land available. Again this can lead to cover damage, ponding and odour problems. It can also cause pollution difficulties due to the run-off of liquors to nearby surface water-courses. Liquor application rates must be sensibly chosen and maintained having regard to the factors influencing the rate of take-up of water, namely soil conditions, crop cover and climate. It is foolish to attempt spray disposal if an adequate area of land is not available.

Spray irrigation is a simple and relatively cheap method for the ultimate disposal of food processing waste liquids. It does require an adequate land area not too distant from the factory site.

Although the method has been associated with crop growth, spray disposal into woodland areas is practicable and offers advantages. Well designed and correctly operated spray disposal installations have been satisfactorily disposing of food waste liquors on to land in a variety of climates for a number of years. A properly engineered and controlled system neither pollutes the environment nor seriously disturbs the ecology of the locality. In the words of the U.S. Department of Health, Education and Welfare[15]: "with proper equipment and controlled application of the waste, spray irrigation will completely prevent stream pollution, will not create odour problems, and is usually less expensive than other methods of waste disposal." For food processors in relatively rural areas with a waste disposal problem, it is a method worth considering.

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